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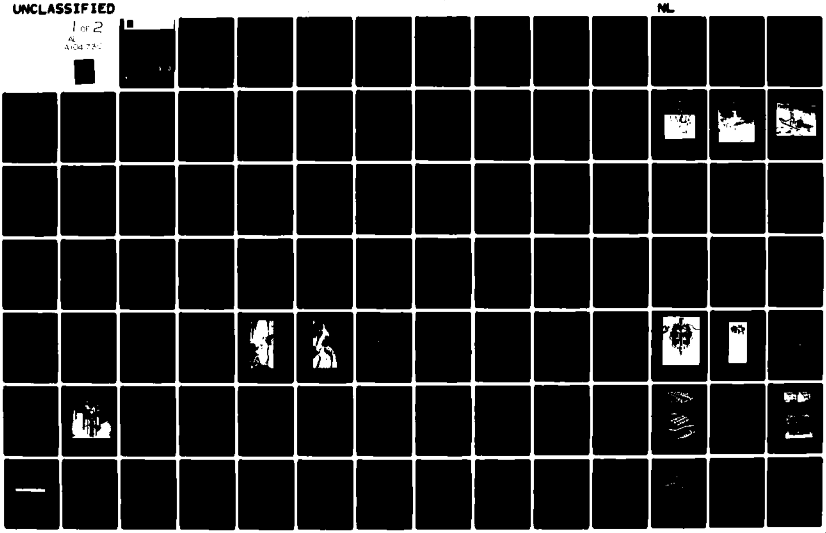

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Maritime Support for Ocean–Resources Development

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Maritime Transportation Research Board

Commission on Sociotechnical Systems

MARITIME SUPPORT FOR OCEAN-RESOURCES DEVELOPMENT

Report of the
Committee on Maritime Industry Opportunities and Requirements
from Development of Ocean Resources

Maritime Transportation Research Board
Commission on Sociotechnical System
National Research Council

National Academy Press
Washington, D.C.
1981

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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FOREWORD

This report is the product of a study group that worked under the auspices of the Maritime Transportation Research Board of the National Research Council. The study was conducted as part of a continuing program of advisory services to the federal government for improving the efficiency and effectiveness of the U.S. maritime transportation system. Progress in developing the resources of ocean waters, the seabed, and those below the ocean floor has placed new and additional requirements on the U.S. maritime industry. To translate these requirements into growth opportunities for an expanded maritime industry role in support of ocean-development activities, the Committee on Maritime Industry Opportunities and Requirements from Development of Ocean Resources has examined the issues associated with ocean development to determine their implication for the U.S. maritime industry. The scope of the study embraces ocean energy systems, offshore oil and gas activities, food from the sea, deep seabed mining, and the use of ocean space.

The committee was an interdisciplinary one, representing the following areas: naval architecture, port planning, shipbuilding, marine science, maritime and ocean policy, fishing, ocean engineering, offshore construction and operations, ocean research, mineral and energy extraction, and maritime systems. James Dunford was chairman of the committee. I extend my thanks to the committee members and liaison representatives for their willingness to serve, their dedication, and their fine work. My thanks also go to the Maritime Transportation Research Board review committee and the staff for their efforts on behalf of the Board.

R. R. O'Neill, Chairman
Maritime Transportation
Research Board

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The committee conducted seven meetings during the course of its investigation, five in Washington, D.C., and one each in Houston, Texas, and at the Woods Hole Oceanographic Institution. At these meetings the committee received presentations and personal insights from government officials and industry representatives on programs, problems, and progress associated with ocean-resources development. We gratefully acknowledge the cooperation, assistance, and counsel of the following individuals who contributed to the committee's work.

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CONTENTS

CHAPTER 1
INTRODUCTION

The nation's needs for energy, materials, and food are focusing attention more than ever before on resources in and beneath the oceans. The development of ocean resources depends very much on tools, facilities, and support supplied by the maritime industry. This study was undertaken to identify the requirements that would be created by expanded development of ocean resources and the corresponding opportunities to build a larger and more vigorous maritime industry.

To do the study, the Maritime Transportation Research Board in March 1978 formed the Committee on Maritime Industry Opportunities and Requirements from Development of Ocean Resources.

The committee was asked to take as its principal objective the definition of the role which the maritime industry can play in meeting the needs of ocean resource development; but also to aim at the development of the elements of a national program to coordinate the diverse activities of maritime industry necessary for ocean resource development.

Maritime Industry Defined

"Maritime industry" in this report includes industries directly involved in developing, constructing, and operating marine vessels--including their navigation, positioning, and control--and marine structures and facilities. The term does not include manufacturers and operators of equipment involved in extracting and processing ocean resources as distinct from traditional maritime activities. The reasons for thus narrowing the definition of the maritime industry lie in the unmanageable complexity of the subject if all affected U.S. industries and activities are to be included. Therefore, the report concentrates on opportunities for marine builders and operators, as opposed to opportunities in ocean resources for U.S. industry in general.

More specifically, the maritime industry as defined here comprises the following elements:

a. Marine construction and engineering services: Basic marine hull and engineering activities--detail design, fabrication, assembly, test, and checkout services.

b. Suppliers of marine systems: Major, first-tier marine subsystems--propulsion machinery, navigation and control mechanisms, communications, cargo-handling gear, and related maintenance equipment.

c. Operations services: Activities related to operating and husbanding vessels and related marine equipment during the operational phases of ocean programs--operations of exploration and oceanographic research vessels, operations of crew and replenishment vessels, manning and servicing marine platforms, and related maintenance activities. Also included are offshore port facility construction and operation.

d. Research and development: R&D activities that traditionally support elements a-c above--advanced design and development of propulsion, navigation, and control systems; vessel operational analysis; research on marine structures and materials; development related to simulation and training.

e. Related science and exploration: Mapping and surveying; analysis of subseabed, seabed, water-column, and surface waters and their resources, including traditional oceanographic research activities. This element includes activities of public and private oceanographic institutes; universities; programs generated by federal, state, and local governments; and nonprofit and commercial ocean-research organizations.

In setting up achievable goals for the study, the committee excluded conventional ocean transportation from the working definition of maritime industry. That element appeared to be outside the purview of a study of ocean "resources" and in addition has been the subject of many analyses and considerable debate on policy.

The Potential of Ocean Resources

The oceans and their resources have long been important to the health and prosperity of our nation. They provide a medium of transportation and food and are strategically valuable as a natural barrier against attack and a means of projecting our economic and military strength beyond our shores. More to the point, a recent study of ocean policy[1] notes that the federal government and coastal states together control an ocean area nearly three times the size of all

publicly owned land in the United States. The search for new sources of energy; the demand for food and minerals and other materials; and the pressure for use of the ocean shore for supporting industry by any reasonable projection will gain importance with each passing year.

The development of ocean resources is favored in the long term by economic forces. Technology for capitalizing on many such resources is available or can readily be made available when costs and benefits come into balance. On the other hand, there are restraints on the development of ocean resources. They include competition for space on the ocean shore and continental shelf, environmental problems, and consequent laws, regulations, and agreements--local, state, federal, and international--that can affect the development of such resources profoundly.

Existing Studies

Ocean resources have been the subjects of numerous studies, assessments, reports, and proposals. The heavy investments in offshore oil and gas have generated an impressive number of documents on all aspects of these important resources. Other sources of energy from the ocean, notably ocean thermal energy conversion, are receiving considerable attention from state and federal governments, equipment manufacturers, and the electric power industry; mulitmillion-dollar experimental programs are under way. Marine mineral resources and deep-seabed mining of manganese nodules, for example, have been studied and reported. Assessments of the seas as sources of food are the province of a long-established industry.

Studies also have been made of a broad range of topics related to development of ocean resources. In 1977, the Maritime Administration published a technology assessment of the effects of offshore resources on the maritime industry.[2] In 1978, the Department of Commerce published a report highlighting issues of public policy involved in realizing the actual and potential benefits of ocean resources.[1] These and many other reports provide a wealth of information: statistics and projections; past and current legislative activities in Congress and state legislatures; discussion of international negotiations and agreements.

Approach to this Study

Although existing studies of ocean resources provide an extensive factual base, they do not, in the committee's opinion, focus sufficiently on the current and potential role of the maritime industry in developing those resources. This study is designed, in part, to give the industry the information it needs to anticipate and capitalize on opportunities in ocean resources. The study was guided, therefore, by the economic and market considerations that guide business

organizations in general. There are, however, other audiences for this analysis. They include the Congress, federal agencies involved in shaping public policy, smaller legislative units interested in promoting and controlling the development of ocean resouces, research and development activities in universities, and governmental private laboratories.

The committee approached the study in three steps: identification of opportunities in development of ocean resources; identification of requirements imposed on the maritime industry by such development; and analysis of actions that the maritime industry and concerned agencies must take to meet those requirements. The committee considered four categories of ocean resources;

1. Energy
    a. Thermal, geothermal
    b. Wave, current, tidal, wind
    c. Salinity gradients
    d. Biomass
    e. Hard minerals
2. Extractives
    a. Oil and gas
    b. Living resources
    c. Minerals (deep sea and continental shelf)
3. Ocean space
    a. Storage and disposal
    b. Ports
    c. Research
    d. Industrial-plant vessels
    e. Recreation
4. Recreation

The committee also established guidelines for the assessment of opportunities. The first is the market for the resource at issue. Usually the strength of the market depends on the likelihood of profit. Public policy sometimes will override the free market in this regard, but in the end it is profit that drives development. The point is typified by ocean thermal energy conversion (OTEC). The concept has been known for decades; the technology is within reach. But only where the projected cost of electric power from OTEC promises to be competit... has the concept attracted serious interest. The maritime industry would play a significant role in full-scale use of OTEC, but that ro.e will materialize only where a market exists or is likely to exist within a reasonable time.

A second guideline for assessment of opportunities is timeliness. At current rates of use of nonrenewable resources, ocean resources will gain economically to the point where they become competitive and will be extracted. However, projections of corresponding requirements for the maritime industry beyond 10 years lack real meaning and almost certainly would not spur the industry to act. The committee,

therefore, chose 1980-1990 as a reasonable period of projection for this study. Opportunities in ocean resources that can be realized in that period will impose on the maritime industry requirements sufficiently near-term to call for immediate action or preparation. A longer-range study might well include opportunities that require technology or economic incentives not yet at hand. But the committee excluded such long-range possibilities because it did not seem reasonable that the industry would find them attractive enough to warrant plans or actions in the near future.

Exceptions to the foregoing guideline are cases in which significant research and development is under way or will be undertaken during 1980-1990. Ocean thermal energy conversion is an example. In many such cases, even though commercial opportunities may not be imminent, the maritime industry can play a part in the development program. These situations were deemed to meet the test of timeliness applied by the committee to opportunities in ocean resources.

In surveying the field of ocean resources, particularly in the areas of energy and minerals, the committee reports on several resources which have been studied and perhaps reported on in favorable terms elsewhere, but which have been judged to fall outside of the time-frame limits for this study. The discussion of these "resources" is included in the report for completeness and to identify the basis for their exclusion from the list of resources considered as opportunities.

Constraints on Development

The committee examined a number of constraints on the development of ocean resources. They include laws and regulations, competition among resource systems for space and facilities, and the availability of a work force.

Laws and regulations generally are in force when the resource is not renewable or where its capacity to renew must be protected. Oil and gas on the U.S. continental shelf are examples of the first instance; the nation's fishing industry is an example of the second. Laws and regulations generated by environmental concerns have become important in almost all of the categories of resources considered here. The analogy with the search for land-based sources of energy and the resulting clash with environmentalists is obvious. The effect is to introduce serious and difficult-to-predict factors into any study of resource potential.

The significance of the constraints imposed by policy, law, regulation, and international agreement was brought forcefully to the committee's attention in its examination of resource-recovery industries. It appears in some instances that the attractiveness of the resource in question was affected as much by the possible course of

laws and regulations as it was by economic considerations. This circumstance certainly seems true of deep-ocean mining of manganese nodules, for example.

A second constraint on the development of ocean resources is the conflict among competing users of the same ocean space. Oil and gas drilling off the East Coast, for instance, has added to the existing competition among ocean shipping, commercial fishing, and recreational activities.

Exploitation of ocean resources also may be constrained by a shortage of trained and willing workers. This constraint already has appeared in the offshore drilling industry, where the arduous work causes a very high labor turnover to the detriment of the entire system.

Implicit in the preceding discussion is the question of national policy on the oceans and their uses. We have no unified national policy. Many policies are directed at individual industries or narrow goals; development is proceeding in several directions, and the government is funding large programs. In short, there is much activity but it is not coordinated. The patterns of growth that would permit the maritime industry to support and capitalize on new opportunities in ocean resources are not clear. Fragmented and conflicting policies in many cases are frustrating developments.

Outline of Report

The succeeding chapters of this report treat the various ocean resources in the manner outlined above. The rationale is given for considering or not considering a given resource in the light of its correspondence with the guidelines for market demand and timeliness. Also given are the requirements imposed on the maritime industry by the development of each resource considered. Further, an assessment is made of the degree to which the industry is prepared to meet such requirements and of requirements unmet or unplanned for.

The committee has developed specific findings for each resource. It has also identified important elements of interplay among systems that are or will be used to obtain resources for the seas. Competition and conflicts have been mentioned. Of great importance--in some areas of overriding importance--is the effect of national policy on development of ocean resources.

Thus the three major elements that run through this report are the pertinent technology and economics, and the influence of our government in creating a favorable climate for the development of ocean resources. The committee believes that the report can do much to help the U.S. maritime industry plan for, and respond effectively to, the opportunities created by such developments, and the federal government to take actions to facilitate the industrial developments.

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2. B.D. M. Corportation. A Technology Assessment of the Offshore Industry and its Impact on the Maritime Industry, 1976-2000. U.S. Maritime Administration. Washington, U.S. Government Printing Office, 1977.

CHAPTER 2
OIL AND GAS

Introduction

Offshore and frontier area development of oil and gas is one of the major resource-development opportunities most often cited as having great potential economic benefit for the U.S. maritime industry. The objective of this chapter is to examine systematically the current activities in such oil and gas development by reporting a broad range of reliable industry information and expert opinion obtained through a comprehensive literature review, authoritative interviews and presentations, and by assessing current worldwide and U.S. development trends to forecast the potential economic efect on the U.S. maritime industry during the 1980's and, in some instances, to the end of the century.

The criteria followed in assessing offshore and frontier area oil and gas development opportunities are quite specific. We have not considered transportation of crude or refined products *per se* as a resource-development opportunity. That maritime industry activity is well established, worldwide in extent, and with a market system beyond the scope of this study. Similarly, neither coal transportation nor the processing and transportation of liquefied natural gas (LNG) or liquefied petroleum gas (LPG) have been considered. The principal focus has been on exploration, development, and production of new resources of offshore and frontier-area oil and gas.

This chapter first assesses worldwide oil and gas resources and the U.S. resource demand. Next the current and forecast capabilities of the offshore industry to exploit the new offshore and frontier-area resources are reviewed. The industry's principal trends and areas of interest are identified. Technological, sociopolitical, and economic constraints that may inhibit or limit the industry's principal trends, areas of interest, and rapid expansion are also identified. After analyzing the resource, the needs, and the constraints, the major U.S. maritime industry opportunities were identified. The chapter closes with a summary of the opportunities and related findings and conclusions. For ease of reader reference, there are repetitive or similar subheadings within each of the major sections of the chapter.

World Resources

An attempt to assess the worldwide resources of oil would not be appropriate for this committee since much attention has been paid to this matter and various published sources differ widely.

The oil industry has published a number of articles which are of an optimistic nature with respect to the extent of undiscovered resources in less well explored areas. A Congressional Report "Project Interdependence: U.S. and World Energy Outlook through 1990" points out the facts on which such optimism is generally based.[1] Chapters XIX and XX provide extensive statistics and data showing that the majority of exploration has been concentrated in the developed areas of the world, primarily in the United States and Canada, and that vast areas of great potential are virtually unexplored.

For example, Chapter XX by Bernardo F. Grossling states that "the United States, Middle East, and USSR jointly possess only about 28.3 percent of the world's prospective areas, yet these areas account for 72 percent of the world's cummulative oil production plus proven reserves. On the other hand, Latin America, Africa and Madagascar, Western Pacific, and the South and South East Asia Mainland possess about 46.5 percent of the world's prospective area, yet they account for only 19.5 percent of the world's cummulative oil production plus proven reserves."[1]

As a specific comparison, the petroleum prospective area of the United States is 2,534,000 square miles (6,599,400 km^2), while that of Africa and Madagascar is 5,035,000 square miles (13,091,000 km^2) and that of Latin America is 4,805,000 square miles (12,493, 000 km^2). Through 1975, 2,424,293 wells have been drilled in the United States since the first Drake well in 1849. However, the best available estimates show that only 105,000 wells have been drilled in Latin America and just 25,850 in Africa and Madagascar.

The argument then goes that a comparable drilling effort in these undeveloped prospective petroleum areas will uncover large, even enormous, new reserves. Aside from the reasonable questions as to the validity of this method of extrapolation, there is, of course, a strong influence to be felt from the political factors that exist now and certainly will be present in the future.

The objective of this summary is to point out (1) that the economic forces will inevitably press the search for oil worldwide in areas which have not had anywhere near the amount of exploration that the United States has had, and (2) that future exploration and recovery activities will be in the most difficult operating areas of the world: the continental margin (includes shelf, slope, and rise); the Arctic and Antarctic; and the remote undeveloped, or jungle areas. However, any projected development of Antarctic areas is forecast to start well after the time frame of this study and thus will not be considered further.

This latter point is emphasized in an interim report by the MTRB Committee on Maritime Services to Support Polar Resource Development titled Antarctic Maritime Service Requirements.[2] The report concludes "there appears to be little incentive for U.S. commercial development of the Antarctic. No immediate marine transportation needs are foreseen for development of biological or mineral resources or for tourism." The report also states that "technology developed for Arctic marine transportation systems will mostly be transferable to the Antarctic should a requirement ever develop."

U.S. Resources and Demands

In contrast to world trends, forecasts of U.S. petroleum production show a consistent downward trend over the next two decades, to the turn of the century. The forecasts for U.S. consumption of petroleum clearly show a continued increase through 1985 with a downturn by 2000 back to a level near the current (1978-1979) rate of consumption. As Table 1 shows, this rate of petroleum use can only be made up by imports that seriously increase U.S. dependence on foreign resources. The report relies on basic projections. Federal policies such as import quotas and measures to reduce consumption could hasten the downturn. Therefore, in the present world circumstances where international petroleum prices are established by OPEC, the adverse impact on our economy will not only continue but will worsen until additional U.S. resources are developed and/or alternative energy sources are found and our petroleum dependence is markedly reduced.

As with the projected worldwide petroleum resources, the principal undiscovered U.S. resources are predicted to also lie mainly in the most difficult operating areas: the offshore continental margins and the Arctic regions of the Alaskan Continental Shelf. The National Research Council's Committee on Nuclear and Alternative Energy Systems, in its report Energy in Transition, 1985-2010,[3] similarly found that domestic oil and gas are becoming more difficult and expensive to find and produce as development moves toward deeper wells and the exploitation of deposits in such relatively inaccessible locations as the Alaska North Slope and Outer Continental Shelf.[4] While U.S. continental land exploration will continue on a large scale, the potential for significant new finds on land is clearly decreasing.

One area of special marine industry interest that has become more economic because of increasing world petroleum prices is the nearshore, shallow water areas along the Gulf Coast, generally in water less than 300 feet (90 m) deep. These areas contain many finds, once considered marginal, that can now be reworked and brought into production. This may provide a significant opportunity for the U.S. maritime industry in both drilling and production equipment and support systems. Deregulation of oil and gas prices will further enhance the activity in such coastal areas.

TABLE 1 Oil and Gas Consumption

Oil (10^9 Barrels per Year)

	1970	1985	2000
U.S. production	3.9	2.9	2.6
U.S. imports	1.1	3.7	2.9
Total U.S. consumption	5.0	6.6	5.5

Gas (Trillion ft^3 per year)

	1970	1985	2000
U.S. productior	21.2	15.0	9.0
U.S. imports	0.8	2.0	1.0
Total U.S consumption	22.0	17.0	10.0

Percent Petroleum Resources
of Total U.S Energy Consumption

	1970	1985	2000
Oil	43.3	42.7	33.7
Gas	32.3	19.6	10.6
Total	75.6	62.3	44.3

Source: Hayes, E.T., 1979, Energy Resources Available to the United States, 1985-2000. Science, 203, 4377: pp. 233-239.

There is general consistency among the several major studies referenced in this chapter, that can be summarized as follows:

- U.S. OIL AND GAS PRODUCTION, BOTH ONSHORE AND OFFSHORE HAS ALREADY PEAKED AND IS EXPECTED TO CONTINUALLY DECLINE THROUGHOUT THE FORECAST PERIOD OF THIS STUDY. The exception to this statement could be the early discovery of giant new fields on either the Offshore Atlantic and/or Pacific Continental Shelf Areas or the Arctic regions including the Alaskan Continental Shelf. However, because of the current rate of exploration in these areas, and the record of the extensive time required to proceed from lease sale to production in today's sociopolitical environment, the two factors almost preclude any such major finds coming on-line in time to significantly change the current trends in U.S. production during the remainder of this century.

• CLEARLY, THE UNITED STATES WILL BE INCREASINGLY DEPENDENT ON FOREIGN OIL AND GAS IMPORTS, WHICH ARE FORECAST TO PEAK IN THE 1980'S AND BEGIN TO DECREASE IN THE 1990'S. This forecast, especially the prediction of decline, may change markedly, depending on global oil exploration and development activities and federal energy policy. If alternative energy sources are not developed, and if nuclear-energy production, because of current fears and pressures, does not grow to fill some of the energy gap, massive social pressure is expected to build during the 1980's to demand that oil and gas resources be developed at a rate near the normal U.S. rate of energy consumption growth, about 3.8 percent per year.

• U.S. PRODUCTION OF OIL AND GAS CAN BE EXPECTED TO RESPOND TO THESE SAME SOCIOPOLITICAL DEMANDS AND ALSO TO THE ADDED ECONOMIC PRESSURE OF AN EVER-INCREASING NEGATIVE BALANCE OF PAYMENT FUELING OUR DOMESTIC INFLATION.

• THE AREAS OF PRIMARY INTEREST FOR INCREASED U.S. PRODUCTION OF OIL AND GAS, i.e., OFFSHORE CONTINENTAL SHELF AREAS, SHALLOW-WATER COASTAL REWORK AREAS, DEEP-OCEAN RESOURCES, AND THE ALASKAN CONTINENTAL SHELF, ARE ALL MARINE AREAS AND CAN REPRESENT SPECIAL OPPORTUNITIES FOR U.S. MARITIME INTERESTS.

Oil Industry Capability

Water Depth

The bulk of offshore operations, exploration, and production for the next 10 to 15 years are forecast to be at water depths of less than 600 feet (180 m).[4] The industry has proven capability well beyond this range; the current drilling record is 4870 feet (1475 m), set by Texaco/Shell off northern Newfoundland in July 1979. Gas and oil are known to exist at even greater depths. This has been proven by the National Science Foundation's Ocean Coring Sediment Program, which found saturated oil sands in water depths of 11,754 feet (3580 m) in the Gulf of Mexico. However, the cost of production, in water depths of 5000 ft or more (1520 m), based on today's technology, would require an oil price of about $60 per barrel (in 1979 dollars).[4]

At today's prices, it is estimated that a discovery in 1500 to 2000 ft of water would have to contain reserves of at least 500 million barrels and be capable of producing 5000 barrels per day per well to be commercially practical. Discoveries of this magnitude represent only 1 percent of the total number of discovered fields to date, both onshore and offshore. Since history shows that only one out of every 10 or 15 wildcat wells strike a commercial field of any practical size onshore or offshore (in shallow water), it would appear that the chances of finding a commercially exploitable field in deep water would be one in a thousand today.[4] The future price of oil and advances in deepwater drilling technology may well alter these odds in a more favorable direction.

Drilling Technology

One encouraging fact is that the technology for economic production of petroleum in water depths over 1150 ft (350 m) is current state of the art. Further, tested modifications and improvements can upgrade this existing technology to make possible regular drilling operation to 5000 ft (1500 m). It is also the opinion of offshore industry experts that, when required, in the next two decades, current research and development will provide the necessary equipment and technology to explore and produce oil and gas in water depths to 10,000 ft (3000 m) or deeper. Examples of three types of drill rigs are shown in Illustrations A, B, and C.

In order to effectively exploit oil deposits effectively at these latter depths, completely automated or remotely controlled supporting and sea floor completion systems must be proven. Subsea completions in depths to 400 ft (120 m) are now state-of-the-art technique with about 100 installations operational worldwide. One 1979 completion by Petrobas in Brazil's Enchova field is operating at a depth of 620 ft (190 m).[5] Currently, research on such completion systems is being conducted. For example, Exxon's full-scale, three well prototype Submerged Production System (SPS) has been undergoing field tests in the Gulf of Mexico since 1977. Testing was successfully completed in mid-1979. This unit, designed for operation to 2000 ft (600 m), can be upgraded to 5000 ft (1500 m) with today's technology; current company R&D efforts to accomplish this are under way. Other companies, such as Shell, BP, Kerr McGee, Phillips, and the French companies CFB and ELF are following Exxon's lead to develop remotely operated seabed completion systems.[6]

Basic Types of Offshore Rigs

A jack-up drilling unit, or platform, is a mobile unit consisting of a buoy and platform that houses the drilling machinery, living quarters, and consumable supplies and is towed from one driling site to another after which it is jacked up above the surface of the ocean by means of columns, or legs, which are either affixed to a lower hull know as a mat or which have feet, or "cans," affixed to the bottom of the legs to limit penetration into the ocean floor.

A semisubmersible is a vessel consisting of a platform that houses the machinery, quarters, supplies, drill derrick, etc. above the ocean surface and is generally nonbuoyant. The platform is supported on cylindrical columns that provide some buoyancy and the water plane necessary to maintain stability when the unit is drilling. These columns, in turn, are generally connected to lower hulls, which provide primary buoyancy while drilling and also provide the entire buoyancy while the unit is in the transit mode.

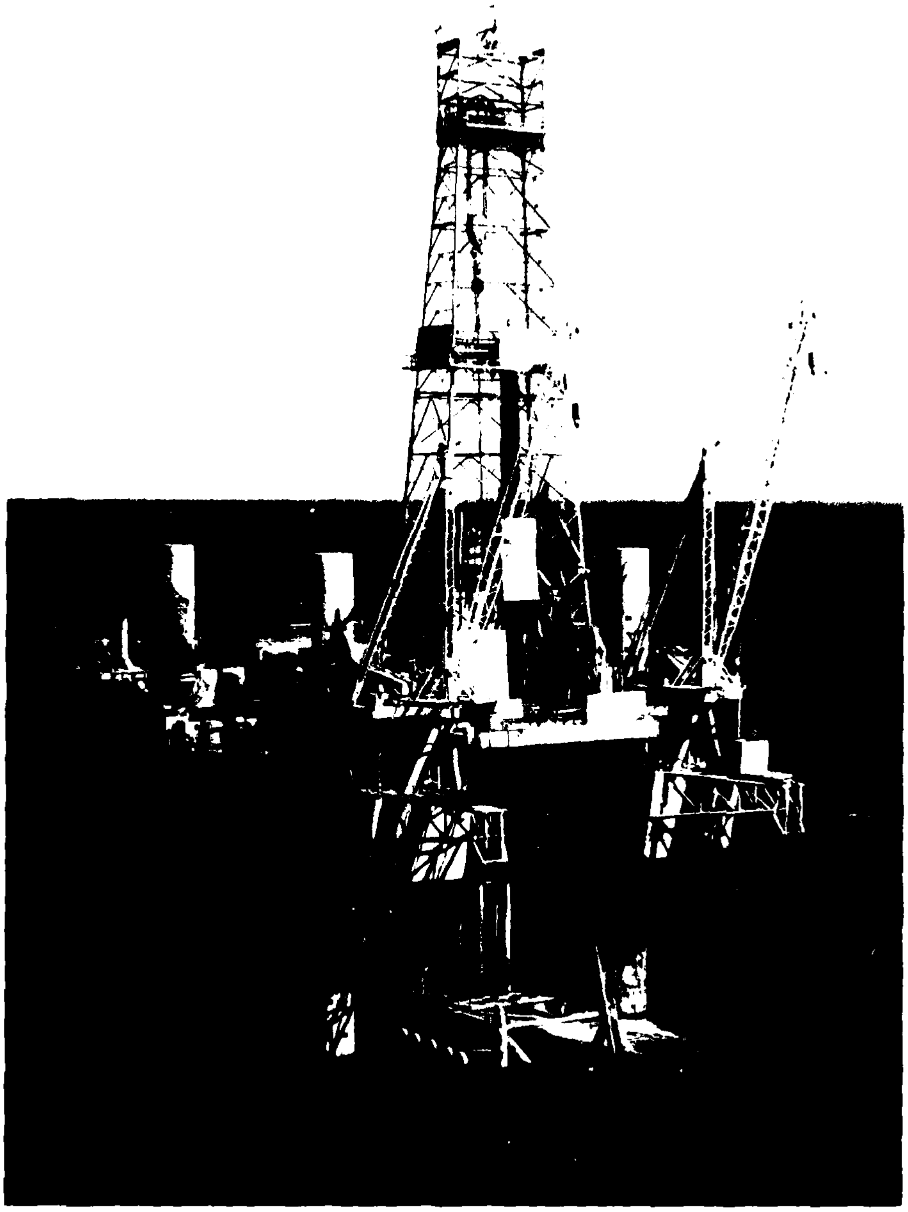

ILLUSTRATION A Typical Mobile Jackup Drilling Unit

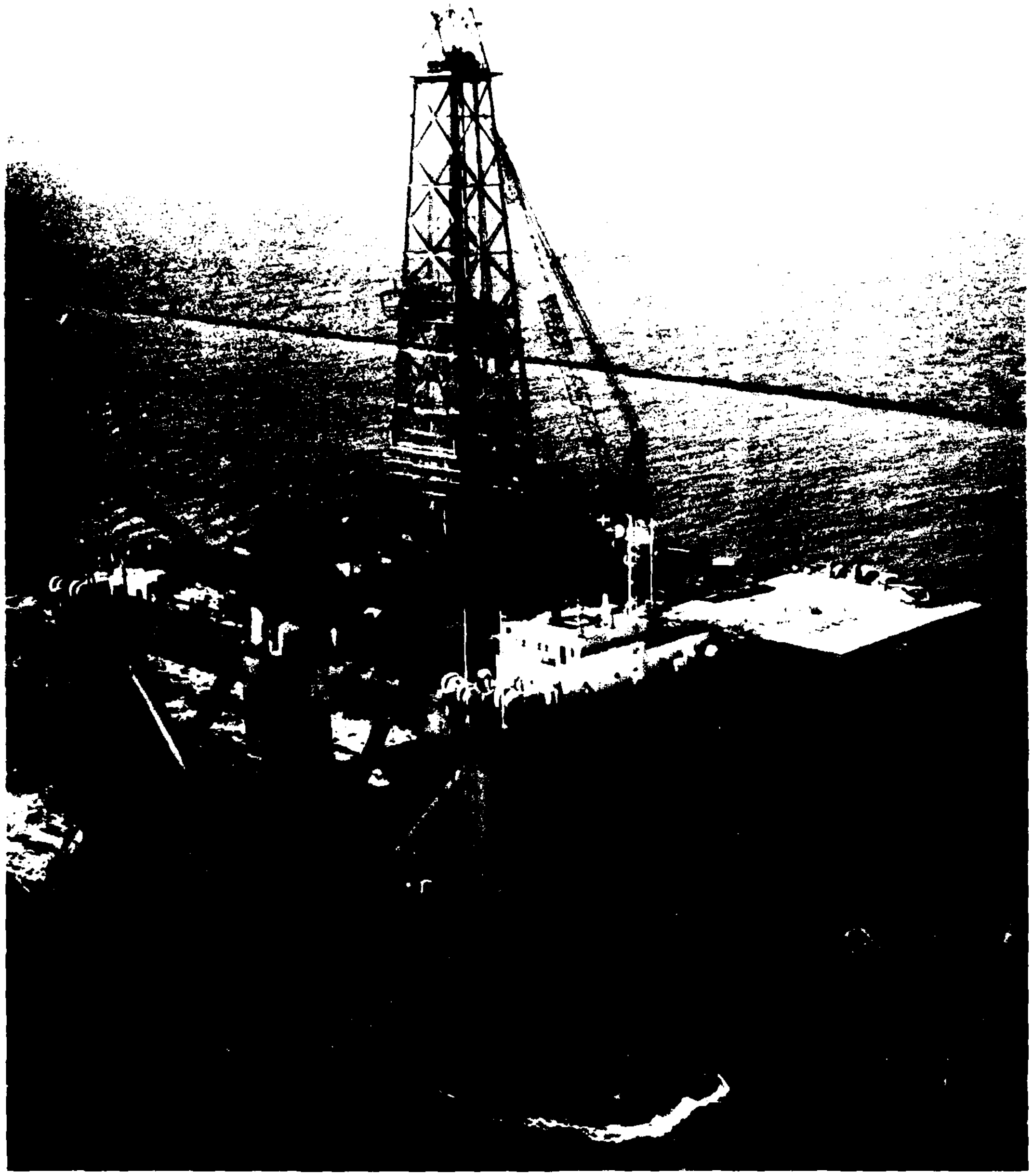

ILLUSTRATION B Semi-submersible Drilling Vessel

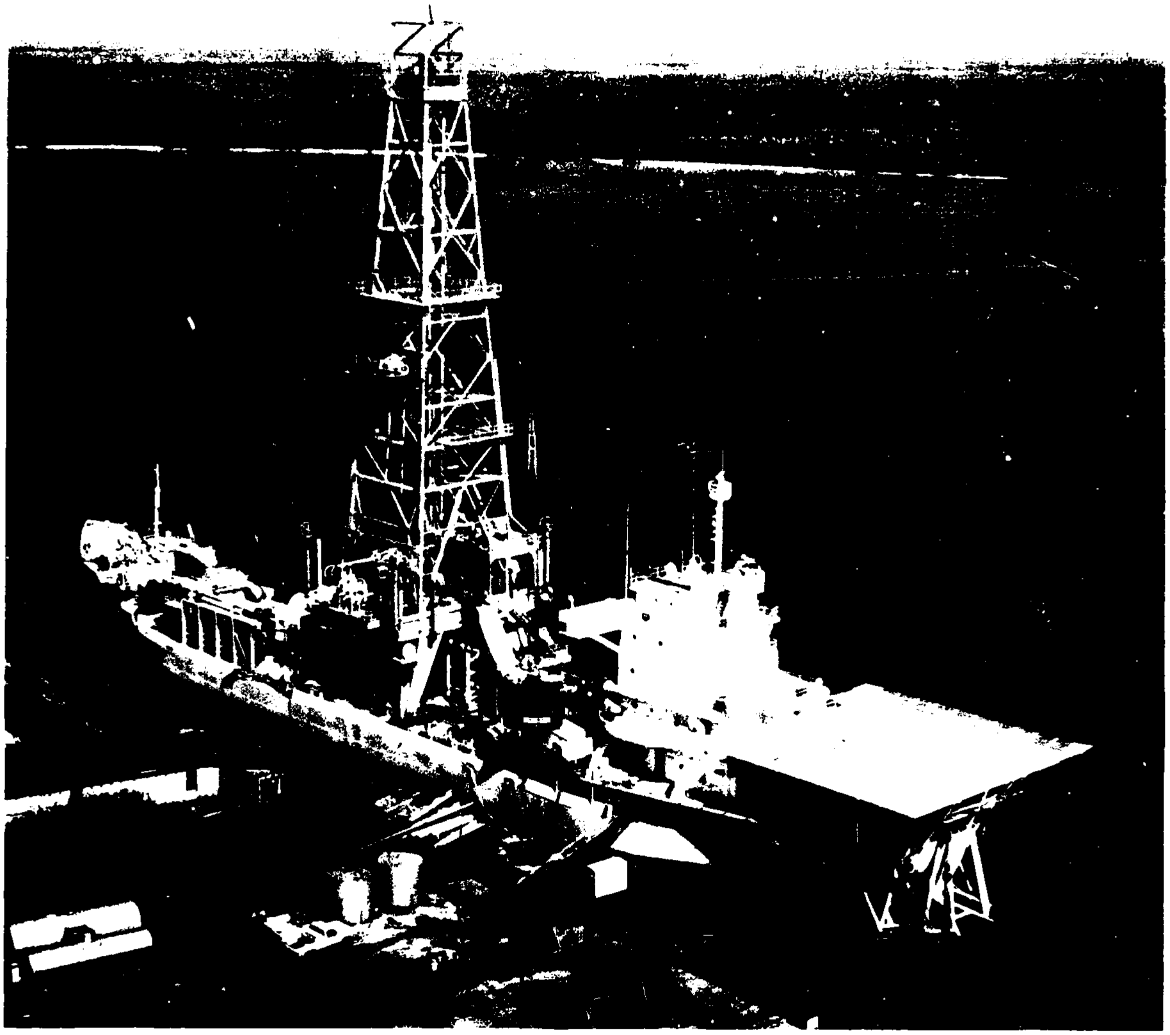

ILLUSTRATION C Typical Drill Ship

A submersible rig floats on hulls while being towed to the drilling site. At the site the hulls are flooded and come to rest on the sea floor to form a stable platform base. The drilling deck is built on long steel columns that extend upward from the hulls and provide safe clearance above the water surface.

Arctic Technology

Major programs by the oil and offshore industries to develop equipment and systems for exploration and development of potential Arctic resources are receiving priority attention in both the United States and Canada. More than 30 exploratory wells have been drilled in the Alaskan and Canadian offshore Arctic areas, and an additional 14 operations have taken place in Hudson Bay and in the Labrador Straits between Greenland and Labrador. Forecasts are that Labrador oil and gas might be produced as soon as 1985, despite the Arctic environment.[7]

Already field-proven by these operations are drilling systems using directional drilling from land sites; artificial islands built in shallow-water areas; natural and artificial ice platforms in depths greater than 800 ft (244 m); and conventional and ice-breaking drillships for summer operations. Extensive research is under way for the development of new systems including air-cushion barges with ice-melting capabilities; semisubmersible, monopod structures with large ice cutters providing the capability for maintaining an ice-free area around the drill structure; and bottom-resting monopod structures having ice-breaking contours to permit ice movement around the structure.

Other innovative systems for Arctic development are under study.[8] These include the submarine drillship and the submarine tanker, both of which are believed by some to be feasible but are high-risk and high-cost systems. Successful production from such Arctic drilling operations will also depend on sea bottom completion systems and on complex pipeline or specialized transportation systems for crude oil movement to refineries.

The U.S. Maritime Administration (MarAd) has conducted a number of Arctic development studies and supported some model test work. The most recent efforts address activities from 1972 and cover a range of concepts including conventional ice-breakers, submarine tankers, Arctic terminals, and air-cushion icebreakers. The Maritime Administration has also organized the Manhattan Arctic Tanker Test Data into an orderly format for use by the U.S. maritime industries. Total MarAd R&D funds expended over that time period on Arctic-related studies are about $2,200,000, as shown in Table 2.

TABLE 2 MarAd Sponsored Arctic Technology

Title	Contractor	Cost ($)	Year
Ice Transiting Time	Wartsila, Finland	416,000	1972
Arctic Marine Requirements	Arctic Institute	175,560	1972
Submarine Transportation - Economics	Martingale Company	21,000	1973
Submarine Transportation - Financing	National Bureau of Standards	11,000	1973
Submarine Transportation - Conceptual Design	Newport News	411,424	1974
Influence of Draft on Ice Resistance	Wartsila, Finland	92,000	1974
Aretic Ice Dynamics	National Science Foundation	133,073	1974
Conceptual Design-Nuclear Ice-Breaking Tanker	Newport News	109,621 12,282	1976 1976
Nuclear Powered Arctic Ship Offshore Oil Exploration	Global Marine	82,690 45,000 1,480	1973 1974 1975
Feasibility of a Tanker Transportation System for Alaskan Northwest Coast	Global Marine	95,797 28,350	1976 1977
Northwest Alaska Transportation Implementation	Global Marine	14,818	1978
Arctic Ship Powering & Development	Arctec, Inc.	8,281	1977
Analysis of the Application of Aircushion Configuration to Icebreaking	J. L. Decker	25,876	1977
Organization of the SS MANHATTAN Arctic Marine Project Data	Arctec, Inc.	115,745	1977
Study of Arctic Terminals for Icebreaking Tankers	Bechtel Corp.	116,530	1978
NPRA Marine Transportation Study	J. J. McMullen	287,261	1978

Constraints

Given the enormous economic and social pressures for the development of more petroleum energy sources by which the United States can reduce its dependence on foreign oil imports, there exist other powerful interests that are having the effect of a constraint on the activities of the oil and offshore industries. The principal factors that we perceive, will be identified and discussed in the following paragraphs in an effort to identify opportunities for the U.S. maritime industry to act and benefit economically in support of oil and gas operations during the balance of this century.

Environmental Protection

One of the important legal constraints for offshore and Arctic oil exploration and development today is the National Environmental Policy Act of 1969 (NEPA) and its implementing rules and regulations. While the NEPA requirements are the basic framework through which oil and gas development plans must seek approval, there are additional steps required by the Outer Continental Shelf Lands Act and its amendments. The NEPA water-quality program and accompanying environmental safeguards were the response to the deeply held concern for the protection of the marine environment. Added to this basic set of regulatory rules is the effect of local action and opposition to the perceived dangers to the local environment. From the standpoint of those striving to find new oil sources, however, the balance between such protection and the need for new petroleum resources offshore may have swung too far in favor of the "protectionist" viewpoint. To support such a view, they cite the lengthy hearing processes and extended review procedures that add significantly to the time and expense required to take all required actions to bring offshore resources of oil and gas on line.

A large part of the environmentalist concern is based on the fear that additional expansion of offshore development increases the risk of possible catastrophic oil spills or related problems. Despite significant amounts of R&D funds spent by both the U.S. Government and private industry there is no proven and guaranteed oil-spill containment and collection system. There is, however, a national oil-spill and hazardous substances pollution contingency plan, which through federal and state officials can coordinate a response to pollution incidents--the National Response Team. This administrative structure is continually being updated as experiences, unfortunate as well as fortunate, enable the planning capability to be tested and tried under actual conditions. A satisfactory level of organizational skills has already been established, although the best planning efforts often are confounded by unpredictable winds and weather and poor seamanship. However, industry and government alike are essentially incapable of containing and collecting oil spilled in the open ocean because it is often the case that wind speeds, wave heights, and ocean current conditions exceed performance capabilities of all existing equipment.

Further, neither the basic mechanisms of wind and wave transport nor the dispersion, solution, and evaporation characteristics of hydrocarbons in water are adequately understood. The lack of knowledge and the dearth of research also constrain the ability to design and build effective open ocean containment and collection equipment.

Offshore oil exploration and production are sometimes blamed as a major contributor to oil pollution in the oceans. This has added to the pressures for constraint that have their strongest voices in the various local communities that fear the consequence of contamination from spills, especially seemingly disastrous ones such as that in the Santa Barbara channel of California in 1969 and the IXTOC blowout in the Campeche field off Mexico in 1979.

The facts of ocean pollution taken as a whole appear to show that despite the sharp reactions to local spills, the offshore oil producing industry is not now a major contributor over all. The 1975 study of the National Academy of Science, Petroleum in the Marine Environment[9] and the NOAA Environmental Research Laboratory Report, Hydrocarbons in the Ocean,[10] April 1976, show that worldwide offshore oil production contributes only 1.3 percent of total hydrocarbons in the world's oceans. The same studies show that 9.8 percent, almost eight times as much oil, is introduced into the oceans by natural leaks and another 9.8 percent by atmospheric fallout, primarily rain contaminated from land-based exhausts, chimneys, and smoke stacks.

More effective oil-containment and clean-up systems for ocean, coastal, and inshore uses do not exist and are clearly required if we are to protect the marine environment adequately. The development, testing, and production of such systems represent an important opportunity for the United States.

Ice Technology

Ice is the major operating and environmental constraint facing the oil and offshore industries, support services, and transportation systems, in the projected move into the areas of the Arctic and Alaskan Continental Shelf. The inability of structures to withstand the extremes of cold, the enormous forces of ice movements, and the added structural loading of ice accumulation provide many research and development opportunities and technology challenges for new and better materials and equipment and for innovative systems and procedures by designers and fabricators. With the exception of those MarAd studies listed in Table 2, and Department of Defense Arctic research, essentially no large-scale organized U.S. R&D programs exist beyond the efforts of the oil industry to solve current operating problems.

In Canada, the Provincial Government of Newfoundland and Laborador is participating in public and private programs aimed at developing new vessel and rig ice operations technology. In cooperation with the

Canadian National Research Council (NRC) Centre for Cold Ocean Resources Engineering and the Newfoundland Oceans Research and Development Corporation, a $40 million to $50 million ice breaking vessel and offshore structure engineering center is planned at Memorial University, St. John's. Facilities at the NRC center, scheduled to be completed in the 1980's, will include a major ship-dynamics laboratory, a 52 ft x 262 ft (16 m x 80 m) ice-test tank, a 52 ft x 656 ft (16 m x 200 m) hydrodynamics tank, and a ship-model production facility. These facilities will make Newfoundland the ice research center of Canada.[11] Similar actions and programs are needed to facilitate U.S. Arctic operations research and development.

It is important to note that ice breaking technology, world-wide, has advanced to the point that Soviet Arctic ports have been kept open year round.[12] These sea lanes will be maintained by a large Russian fleet of ice breakers, including the world's largest, the nuclear powered ship LENIN.

Manpower

One of, if not the, most expensive and variable elements in offshore industry operations is manpower. The turnover rate is relatively high on offshore production platforms. While the pay scales are high, working conditions are confining and hazardous; the work is intensive, with long hours. Personnel training costs represent a major factor in offshore operations, and there are undoubtedly opportunities for psychological study and research on ways to better select and motivate personnel. Similarly, there is a clear need for improved training systems. New and expanded offshore rig production will exacerbate the existing manpower problem. Training schools supporting the U.S. maritime industry could make a major contribution in resolving critical and costly manpower shortages.

Use Conflicts

The difficulty of offshore leasing because of conflicts with fishing, shipping, and recreation interests are often serious constraints to the offshore oil and gas industry in certain geographic areas. The effect of this "use conflict" factor on the maritime industry's support opportunities is probably secondary or indirect and can be either positive or negative. Innovations in equipment, facilities, or services relative to recreational interests or shipping-lane safeguards could have positive maritime industry benefits. However, since this factor is believed to be of secondary importance to this part of our study and to be more closely related to the section on space or fishing, it will not be considered further here.

Service and Base Support

Every offshore and frontier region of oil and gas operation will require major logistic and operating-base support for every phase from exploration to final production. The demands for special equipment, especially support craft, represent a significant maritime industry opportunity for R&D, construction, and operation. The major offshore operating companies have core personnel and equipment that are moved to new development locations, primarily during the initial exploration phases. However, these early phases still require services and base support and can present significant opportunities to local maritime industries.

The drilling of exploratory wells in the Baltimore Canyon area presents a good example of what does happen as such activity accelerates. The first rig commenced drilling in March 1978. One year later, when there were six rigs operating, there were 1444 people based in or working out of Davisville, Rhode Island in support of the drilling rigs. Of the 1444, 588 (41 percent) were hired locally. There were 90 oil-field service companies that either shipped material into Davisville, supplied specially trained people, or opened offices in Davisville. Also, 97 local companies benefited in some way from the drilling activity in the Baltimore Canyon.

As an area is developed into a production operation, the use of local maritime equipment, facilities, and industrial support increases. The adaptability and response of the maritime industries or the resistance by local planning authorities in an area of oil and gas development will largely determine the extent of the opportunity and economic benefit received. However, an active offshore or frontier oil operation will probably not be strongly deterred by local conditions; the services and support will simply be obtained from the nearest available alternate source at somewhat increased costs.

Physical Environment and Weather

Basic to every field operation is the need to contend with the physical environment and weather conditions that exist in the area, both the means and the extremes. This is dramatically demonstrated by the ongoing North Sea experience, where essentially fair-weather, Gulf of Mexico technology was transferred to one of the most hostile marine regions in the world, the North Sea. Initially, many mistakes were made, service boats were lost, a few rigs collapsed or overturned, and pipe-laying systems could not operate except for a few days a month on the average. Yet the oil industry has largely overcome the initial problems; necessary changes, innovations ,and developments have been made. Entire new systems were designed and built, creating major new maritime industrial opportunities both directly and indirectly. Still, ocean systems are subject to the vagaries of environment and materials. Failures can and will occur despite the best engineering efforts, as

evidenced by the sudden and catastrophic failure of the semi-submissible platform Alexander L. Keilland in the North Sea in April 1980 with the loss of 123 lives.

The Arctic areas are a challenge now, requiring supporting equipment, and systems must be developed and proven. The deeper-ocean resources will be a challenge tomorrow. The maritime industry has the opportunity today to anticipate, extrapolate, innovate, and prepare to support this new frontier with its severe environment and weather conditions. Thus, the maritime industry can be ready for the anticipated oil industry operations of the late 1980's and 1990's and to benefit from these areas of future development.

Government Regulation, Inspection, and Safety Certification

The rules, criteria, and conditions that must be met by the designer, builder, and operator to assure the reliability and safety of offshore and frontier equipment and installations are operating constraints. They are related to the environmental protection issue through permit requirements. These operational regulations and requirements are, for the most part, engineering based, and they represent maritime industry opportunities for services and equipment to support compliance by the offshore oil industry. A primary example is the recently issued regulation for underwater inspection of platforms and structures. New industries and equipments have been developed, such as remotely controlled robot vehicles and indirect analysis and assessment systems using natural frequency measurement and analysis techniques for entire structures.

While initially the regulations may constrain or inhibit an offshore or oil industry operation, technology, equipment, and techniques must be developed to comply with the regulations so that operations can proceed. Analysis of each regulation or requirement as issued in order to identify the industrial opportunities in support of oil and gas developments can be of benefit to the U.S. maritime industry.

National Energy Policy

Many instances of difficulties, which the lack of policy has placed in the path of increased development of offshore oil and gas resources, were studied by the committee. However, despite a great deal of current attention, the problems in setting such a consistent and enlightened policy are obviously great and the decisions which will solve the problems have yet to be made. The committee did not consider its mandate to include a study of this large subject and, therefore, notes only such matters as the increasingly long time required for obtaining drilling permits, the lack of a stable federal offshore leasing program, and the volatile situation of oil price regulations as examples of problems which await a national policy for relief.

U.S. Maritime Opportunities

The U.S. maritime industry has benefited greatly in construction, conversion and repair, and supply and service activities resulting from offshore oil and gas developments to date, both worldwide and in U.S. waters. The increasing world pressure for expanded oil and gas exploration and for frontier region development bode well for the future. Clearly, there are under U.S. control three areas of primary potential for exploration and development during the next 15 to 20 years. These are (1) the coastal continental shelf areas of the 48 contiguous states, in 600 ft (180 m) or less water depth; (2) the Alaskan Arctic and Alaskan continental shelf areas; and (3) the shallow-water rework and previously marginal areas, principally in the Gulf of Mexico. The deep ocean areas, i.e., water depths of 2000 ft (600 m) or more, will be increasingly explored during the remainder of this century, but production development will probably not be economic unless a massive new field is discovered. Some industry experts believe that the most probable area for U.S. deep-ocean activity is the Gulf of Mexico, while others believe that the 1980's will see activity off all three coasts.[4]

There was in 1979 widespread pessimism in the offshore industry about the prospects for significant finds in the Atlantic continental shelf areas.[13] Initial optimism has cooled since 1970 estimated reserves of 30 billion to 40 billion barrels were scaled down, most recently by the U.S. Geological Survey (USGS), to 2 billion to 4 billion barrels. The second offshore tract sale in the Baltimore Canyon area attracted bids on only 40 percent of the area offered, with a dramatically low average bid of less than $950,000 per tract. While the protracted delays in the Georges Bank lease sales generated further pessimism, the sale when it was finally held on December 18, 1979, generated larger than expected response. Recently, Chevron has made a significant discovery off Newfoundland which should lead to further activity in the area, and Mobil has made a discovery near the Sable Islands. In addition to these recent discoveries, there is continuing interest and expectation for the U.S. Southeast Georgia Embayment area.

The reader must remember, however, that most exploration had ceased, and, reportedly, Phillips Petroleum was drilling "one last well" when the Ekofisk field was discovered. The activity, optimism, and expectations in the North Sea then were at an equally low, or even lower, ebb than now exists relative to the Atlantic continental shelf.

Offshore Drilling Projections

Trends are, therefore, almost impossible to forecast. Straight-line projections for the next 15 to 20 years are probably conservative, but there is little cause to be more optimistic. The extreme economic pressure of world crude oil prices and OPEC control, coupled with recurring possibilities of petroleum product shortages of heating oil

and gasoline on the U.S. domestic scene, will surely force greatly increased offshore activity from now to the end of the century. However, future political trends will also significantly influence the amount of offshore exploration and production activity during the next 10 to 20 years.

Figure 1, the record and projection of the number of offshore wells drilled in U.S. waters, has been taken from MarAd Report No. MA-RD-940-78001, prepared by the BDM Corporation in August 1977. These data have been modified and updated using the latest statistics reported in the June 20, 1979, issue of Offshore, "Worldwide Drilling and Production."[14] Based on these later statistics, we estimate that the number of U.S. offshore well completions per year will rise from about 1200 to 1400 in 1980, will approximately double to an annual high of 2200 to 3200 by 1990, then increase another 30 to 50 percent to 3200 to 4800 wells annually by the year 2000.

Using recorded industry data from 1970 to the present (see Figure 2), we have identified the total number of rigs of all types working worldwide each year and the total number of wells completed worldwide (excluding Russia, China, and Lake Maracaibo in both cases). Dividing the number of wells by the number of rigs we have obtained a gross rate indicator of completed wells-per-rig-per-year. By this analysis we have an average rate of 5.2 wells per rig for the five years, 1974 through 1978.

As Figure 2 shows, this average well completion per rig year figure has steadily declined. This is primarily attributable to the movement of offshore exploration and development drilling into the more difficult frontier areas, including the Arctic and deepwater.

As demand for petroleum has increased, the U.S. percentage of participation in the response to that demand has remained relatively steady. We are beginning to see that the U.S. response to world petroleum prices and U.S. energy demands will markedly increase the rate of U.S. offshore leasing activity. The committee concludes therefore that the U.S. percentage participation in the market will remain steady. Further, as the market expands numerically over the next 10 to 20 years, a U.S. to worldwide well-completion ratio of 45 percent is a realistic and reasonable projection.

Historically, the U.S. maritime industry has not responded quickly to changes in design, facilities, techniques, or processes. The offshore industry, on the other hand, is a dynamic, quick response, action-oriented, industry. A major challenge and opportunity for the U.S. maritime industry will be to develop the ability to respond and support the rapid expansion of U.S. offshore and Arctic region oil and gas activity that seems to be inevitable during the next 20 years.

Skills, technology, materials, designs, and facilities that do not now exist will have to be developed. The ability to anticipate, to

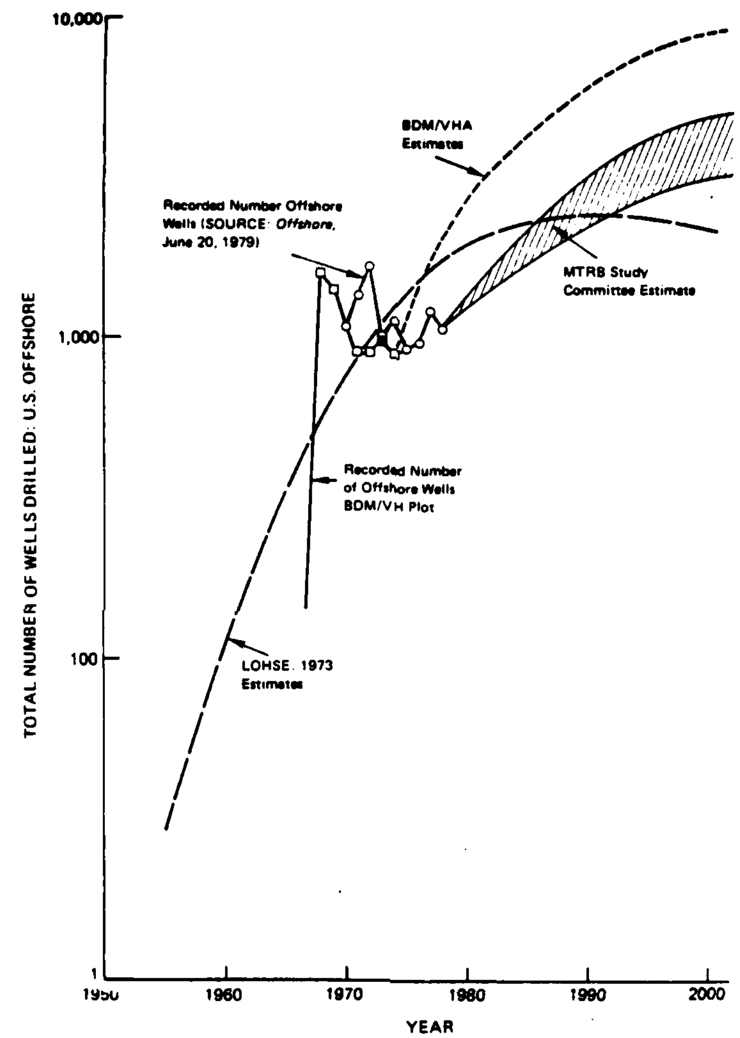

FIGURE 1 U.S. Offshore Wells Drilled

Source: BDM Corporation, 1977, A Technology Assessment of the Offshore Industry and its Impact on the Maritime Industry 1976-2000. U.S. Maritime Administration, Washington: GPO, 1977.

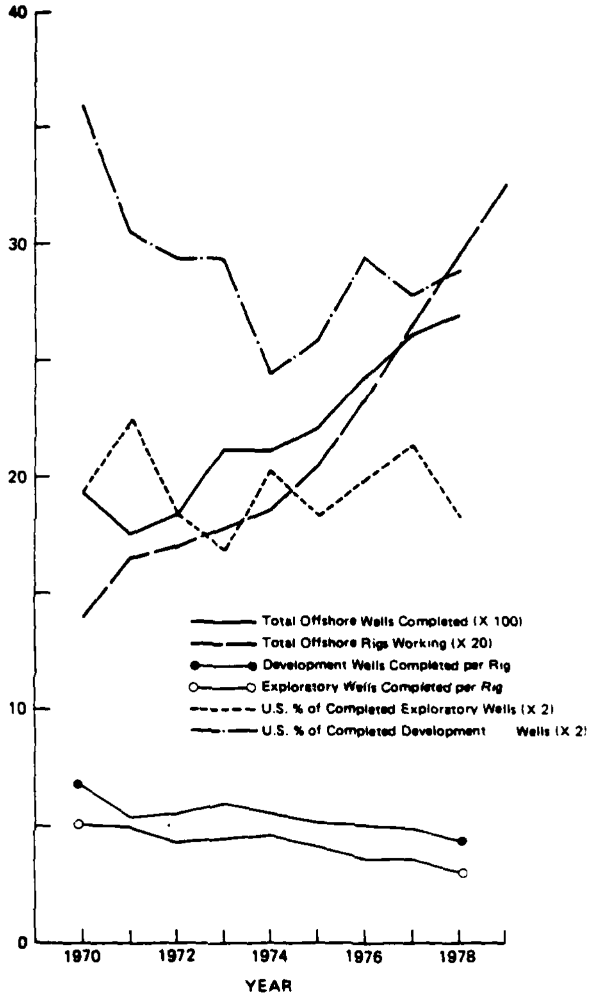

FIGURE 2 Recent U.S. Offshore Oil Well Activity

Source: BDM Corporation, 1977, A Technology Assessment of the Offshore Industry and its Impact on the Maritime Industry 1976-2000. U.S. Maritime Administration, Washington: GPO, 1977.

respond quickly, and to produce efficiently and effectively will determine how much benefit accrues to the U.S. maritime industry.

Industry-government cooperation in high risk, advanced R&D can facilitate the response of, and provide important benefits to, the entire maritime industry. A good example of this type of cooperative R&D is NSF's Ocean Margin Drilling Program that seeks to extend current offshore drilling technology to depths of 4000 m (13,125 ft.) to research new riser technology, and to perfect "down-hole completion" capability. Industry-government support for research in academia through such programs as NOAA's National Sea Grant College Program; NSF's Industry-University Joint Research Program; and the provisions of the newly enacted Public Law 96-480 which establishes the Office of Industrial Technology in the Department of Commerce and Centers for Industrial Technology in universities and non-profit institutions to facilitate transfer of technology innovations to industry, are other means available to aid the maritime industry to develop the needed technology for the future.

Offshore Drilling Rigs and Platforms

At the beginning of 1980 there were about 442 mobile drilling units worldwide of all types, i.e., jack-ups, submersible rigs, semisubmersibles, and drillships. Of this total, half, or 222, are jack-up rigs. Included in this total, but currently under construction worldwide, are 72 rigs, of which 42 were scheduled for delivery in 1979. The new construction includes 59 jack-up units, 2 submersible rigs, 5 semisubmersibles, and 6 drillships. The existence of new construction submersible rigs (strictly shallow- water rigs) and the preponderence of jack-ups clearly reflect the industry's current interest and supports its forecast that the industry's effort will be in the shallow water [less than 350 ft (107m)], in coastal and offshore areas, for the next decade or longer. Table 3 shows the capabilities of various rig types.

This report would be remiss not to mention the subject of fixed platforms utilized for development drilling and production of offshore wells. It is considered, however, that with the present state of the art (in existence for 20 years), the future developments will come slowly through improvement rather than breakthroughs in technology. It is also considered that those companies at present engaged in platform fabrication and erection have sufficient equipment and capacity for both near- and long-term requirements. Therefore, although there is a significant continuing opportunity, the committee believes that it is not a growth opportunity.

The employment record of offshore rigs for the past year substantiates this shallow-water focus and trend. Throughout 1978 and 1979, jack-ups and submersibles have enjoyed essentially 100 percent employment. Those not working were down because of equipment failures

TABLE 3 Comparison of Mobile Offshore Drilling Rig Capabilities

Rig Type	Stability	Mobility	Maximum Water Depth Capability
Submersible	Excellent	Poor	80 ft.
Jackup	Excellent	Fair	400 ft. (600 ft. Two-stage model under development)
Drill ships and barges	Fair	Excellent	600-1500 ft. (New units being developed are capable of drilling in depths exceeding 3000 ft.)
Semi-submersible	Good	Good	600-1000 ft. (New units being developed are capable of drilling in depths exceeding 3000 ft.)

or repairs, not for lack of opportunity. On the other hand, less than 85 percent of the available floating rigs (ships, semisubmersibles, and barges) have been employed; those working in deep water have numbered only about 30 percent of the total available, while the difference of 55 percent are working shallow-water areas because jack-ups or submersibles are unavailable.

Since 1954, the worldwide rate of construction of offshore rigs has ranged from a low of three jack-ups in 1954 to a peak of 63 units in 1976. During this same period U.S. shipbuilders and fabricators have delivered 14 to 16 rigs per year in seven of those years, with the peak delivery of 24 units in 1976. It is estimated that existing U.S. shipbuilding and construction facilities could deliver 30 to 35 units per year at near capacity.

Of the 442 operational rigs of all types listed in the 1979-80 Directory of Marine Drilling Rigs, the breakdown is: jackups, 222; submersibles, 22; drillships and barges, 83; and semisubmersibles, 115.[15] The great majority of existing rigs of all types were built in the United States as shown in Table 4.

Rigs used for drilling in U.S. waters can be built in any shipyard worldwide, because there are no existing regulations that prohibit use of foreign-built rigs in U.S. waters. However, transportation costs and

Table 4 Sources of Offshore Rigs - All Types, Worldwide

Where Built/Building	Number	Total (%)
U.S.	239	52.5
Singapore	39	8.6
Japan	31	6.8
Scotland	15	3.3
Holland	15	3.3
Norway	14	3.1
Canada	14	3.1
France	11	2.4
All others (16 nations)	77	16.9
Total	455	100.0

maintenance requirements greatly favor U.S. builders for rigs working in U.S. waters. Therefore, our study of future construction opportunities takes the position that all new rigs working in U.S. waters during the next two decades will be U.S. built. Further, the opportunity exists for the U.S. maritime industry to build a large percentage of the new rigs to satisfy worldwide demand.

Another element to be considered is the replacment of outdated or worn-out rigs. The average age of all existing jack-ups is over 10 years, and there are still in service 37 rigs over 20 years old. During the next 10 years, an additional 88 rigs will reach 20 years of service and become candidates for replacement.[16] We estimate, therefore, an average age replacement of 10 rigs per year worldwide.

Using the data presented in Figures 1 and 2, we estimate the maximum and minimum number of rigs required to drill the forecasted U.S. offshore wells as follows:

(a) Maximum number of rigs: divide the high estimate of wells per year by the minimum rate of 4 wells/rig/year.

(b) Minimum number of rigs: divide the low estimate of wells per year by the maximum rate of 5.2 wells/rig/year.

Then, using the average number of rigs required for U.S. offshore work as 45 percent of the worldwide rig demand, the worldwide rig forecast was developed. The result of this analysis is shown in Figure 3.

Considering many factors, i.e., (1) significantly increased offshore exploration and development, (2) areas of primary interest, (3) water depth, (4) cost of construction, (5) number of rigs available, and (6) age, it seems reasonable to predict that for the next 10 to 15 years, the U.S. construction demand will be primarily for jack-up and submersible rigs. Table 5 summarizes the worldwide offshore rig-construction opportunity forecast for the U.S. maritime industry.

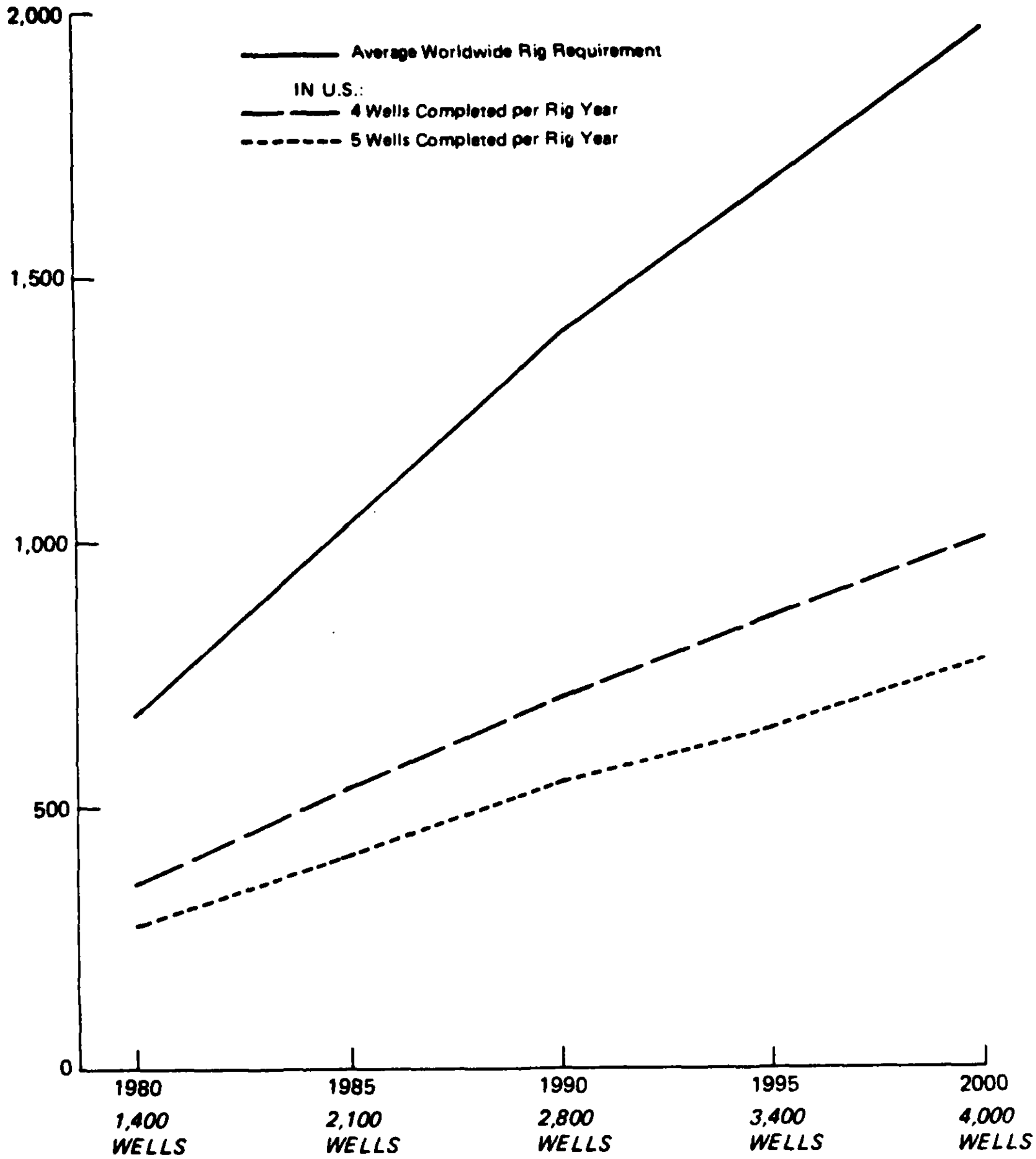

FIGURE 3 Worldwide Rig Forecast

TABLE 5 Offshore Rig Construction Forecast, All Types, Worldwide

	1980	1985	1990	1995
Existing worldwide requirements Figure 3		1030	1380	1670
Existing rigs, 5 years previous	500	500	1030	1380
New rigs required		530	350	290
Age replacement 10 per year		50	50	50
Total construction		580	400	340
Average construction per year for preceding 5 year period, worldwide		110	80	70

The committee estimates that the U.S. maritime industry will fabricate, based on recent history, 50 percent of the worldwide demand for rigs. Therefore the estimated rig construction opportunity is as follows:

1980-1985	50-60 rigs/year
1985-1990	35-45 rigs/year
1990-1995	30-40 rigs/year

This takes into account an expanded offshore exploration and development effort, which the committee believes will begin to develop strongly in late 1980 or early 1981. Without such expansion, our projected construction rate between 1980 and 1990 could be cut in half. The starting point will also shift to follow the initiation date of greatly increased offshore exploration and development efforts.

The rig designs and materials are forecast to remain basically unchanged, i.e., steel not concrete. The U.S. House of Representatives, 95th Congress, Committee on Science and Technology report Energy from the Ocean,[17] April 1978, Chapter 8, thoroughly reviews the trends in offshore oil and gas development. This report finds that concrete construction for offshore rigs and platforms generally requires deeper water than is available for U.S.-based construction. Except for a few special concrete designs, U.S. shipbuilding and heavy-construction industries generally favor steel fabrication.

Drillships and barges are not forecast to experience any significant increase in demand in the near future. However, semisubmersibles are a different story. We have recently seen

contracts awarded for the construction of new units, and there are indications that demand will exceed supply for a period of time. U.S. construction will probably be limited unless policy actions are taken to enhance the U.S. maritime industry's competitive position in the world market. Such support is needed but unlikely to be effected.

Although it has been noted earlier that operations in the next decade or so will not concentrate in the deeper areas, the offshore industry is fully motivated and active in the research and development of innovative exploration and production rigs necessary for deepwater and frontier operations of the future. These are exemplified by the deepwater platforms such as Hondo off Santa Barbara and Cognac recently installed in over 1000 ft (330 m) of water in the Gulf of Mexico and by research on buoyant towers, guyed towers, and tension-legged platforms, to cite a few other examples.

The development of special rigs for Arctic operations is the most active opportunity for participation and constribution by the U.S. maritime industry. The proceedings of the 1979 Offshore Technology Conference are replete with papers reporting studies and research related to every phase of Arctic operations. These opportunities will be discussed more fully below.

Support/Service Vehicles

Offshore support and service vehicles represent a major U.S. maritime industrial component worldwide. There are 152 companies that own and operate about 3000 service/support vessels classified as tugs, tug/supply, supply, utility, crew, and other.[16 18] Of this total, the 30 largest marine operators own 60 percent of all the vessels. Half of the top 30 operators are U.S. companies, and they control one third of the world's inventory of support/service vehicles used by the offshore industry. The world's largest operating company, Tidewater Marine Services, Inc., New Orleans, owns and operates about 10 percent of the world's inventory of support/service vehicles.

The replacement value of the 3000 service/support vehicles is estimated to exceed $4.5 billion, according to a 1979 survey of the Marine Transportation Fleet.[19] The ratio of service to support vehicles is closely tied to the number of operating rigs engaged in exploration and development operations. Production support requirements are relatively stable and a lesser demand on the service industry. As offshore exploration and development activity expands in the next 20 years, construction and operation of service/support vehicles will increase accordingly.

However, Damon B. Bankston, President, Tidewater Marine Service, Inc., cautions that the uncertainty and cyclic nature of offshore activity, coupled with the increased sophistication and rapidly

oscillating costs of marine service equipment, vessels, and operations, requires equally sophsticated management, planning, and control.[20]

There will be need continually to upgrade, replace, and increase the existing service/support fleet, now and for expanded operations in the future. A general forecast of moderate construction activity over the next few years, including both added inventory and replacement units, is probably about 10 percent of the fleet per year. The U.S. maritime industry should expect a continuation of the current level of construction activity for the next three to five years, followed by a significant increase in the mid-1980's in response to the expected increase in offshore exploration and development then.

Arctic/Ice Technology

The U.S. areas of greatest resource potential, according to the oil and gas experts, are also the areas of greatest difficulty--the Arctic regions of Alaska and the Alaskan continental shelf. The ability to operate in extreme cold have been demonstrated by Prudhoe Bay and Cook Inlet developments. But the most severe problem and the greatest challenge is ice. The overwhelming massiveness of icebergs, icefloes, and pack ice are difficult to comprehend until experienced; and the forces of such ice in motion (as it is almost constantly) are virtually irresistible. Equipment and systems must be developed to function efficiently and reliably while surviving in this ice environment.

Despite U.S. activities to date, much knowledge and experience is lacking. An entirely new technology must be developed. The opportunities for research and development are essentially endless. Recognition of this problem by the Canadian National Research Council and the Provincial Government of Newfoundland and Laborador through their national commitment to, and support of, joint research efforts by the Centre for Cold Oceans Resources Engineering, the Newfoundland Oceans Research and Development Corporation and Memorial University, St. Johns, is cited as a great, forward-looking action. To promptly, safely, and effectively realize the Arctic's potential as a major oil and gas resource, the United States would have to proceed with a similar massive R&D effort. To develop the required technology, materials, and systems, such an investment should be jointly supervised by industry, government, and academia.

Arctic Operations

Transportation is the key element to successful development of the nation's Arctic petroleum resources. The Society of Naval Architects and Marine Engineers (SNAME) in their Technical and Research Report R-26, March 1979, provide the following summary of the current situation:

Within the next two decades, major capital investments will be required for transporting newly developed Arctic oil and gas fields inasmuch as the present facilities are not designed to handle the anticipated production through the year 2000. With this view in mind, it is virtually imperative that marine transportation alternatives be developed to permit the evaluation of future capital investments for Arctic transportation. The ability of marine transportation to compete with alternative modes of transportation is currently limited by a lack of confidence in the Arctic marine technology and in particular the lack of experience in marine Arctic operations.

In assessing the Arctic Marine Commerce status today, we find a petroleum industry, a shipbuilding industry, and a general marine community which recognizes the potential of the Arctic regions but who have not yet undertaken coordinated research to provide the transportation technology required in the future. The petroleum companies frequently perform research as it relates to near-term development. The shipbuilding industry does relatively little research and it is usually directed towards immediate improvements. Yet the development of Arctic marine commerce is a many-year, multi-phased research program. We recommend that the Federal Government take the initiative in developing a plan for marine Arctic transportation to meet the energy and mineral needs of the United States in the foreseeable future.[21]

The SNAME report recommends specific R&D program elements and assigns priorities to each. It is interesting to note that in the 1976 Report of the National Planning Conference on the Commercial Development of the Oceans held under the joint sponsorship of MARAD, NOAA, the Department of the Interior, and then ERDA (now the Department of Energy), the Oil and Gas Panel said essentially the same things and made similar recommendations.[22] Combining these recommendations with industry inputs[23] the committee finds that the areas of greatest need, representing the best opportunities for the U.S. Maritime Industry are as follows:

Ship and Platform Technology: Generate reliable data on ice forces by model and full-scale experiments that will facilitate ship and platform design and construction for successful Arctic offshore and coastal operations.

Ice-Breaking Technology: Develop improved, innovative methods for opening and keeping open marine areas both coastal and offshore, to facilitate drilling operations, production, and transportation of crude oil and gas.

Iceberg/Icefloe Control: Develop systems that can protect coastal and offshore installations, both fixed and mobile, by directing or deflecting the motion of icebergs, icefloes, and pack ice away from areas of exploration, development, and transportation activity.

Submersible/Subsea Systems: A recurring idea for Arctic oil and gas development, production, and transportation is the use of submarine systems. These have been studied extensively. Some believe the concept is feasible; a few consider it practicable, especially coupled with nuclear power. The U.S. maritime industry has the knowledge and experience to develop such a system, should conditions dictate the need. However, the time frame lies beyond that being considered in this study, and is noted here only for completeness of record.

Special Support Systems for Deepwater Operations

The Outer Continental Shelf Lands Act assigns responsibility for inspection and certification of bottom mounted rig and platform structures to the U.S. Geological Survey (USGS) of the U.S. Department of the Interior. Regulations requiring underwater inspection and nondestructive testing of welds and joints, coupled with other underwater services, such as inspecting bottom-mounted equipment, inspecting and working on pipelines, seafloor completion systems, equipment recovery, and emergency and casualty correction, have caused underwater service to be one of the fastest developing activities related to offshore oil and gas development and production. As these operations proceed into deeper waters, the effectiveness and expense of diver operations rapidly become limiting. Submersible service systems have proliferated rapidly, from the common manned working vehicle with articulated arms, with or without diver lock-out systems, to specialized welder habitats, to remotely controlled, unmanned robot units, to the unique one-man diving suit, submersible JIM. The article, "Undersea Work Vehicles," Sea Technology, April 1979, reports that for the first time, the offshore industry is now using remotely operated vehicles (ROV) for more submerged time than manned submersibles.[24] This support industry now operates more than 100 ROV's and 80 manned submersibles, with innovations and improvements being added regularly.

Current research is focused primarily on the development of true robot systems, unmanned and untethered for the deep ocean and areas of relatively high-speed water currents. Tethers can create too much drag and require too much power under such conditions so that unmanned, untethered robot systems represent a breakthrough opportunity for the U.S. maritime industry.

Pollution Containment and Collection Systems

As long as oil is produced offshore or transported on the high seas, oil spills will occur. The general public reaction against potential environmental damage from oil has centered on the more dangerous inshore or local impacts, which threaten to accompany any spill. This has resulted in added government regulation and control. Further, this committee believes that the offshore industry and the oil

companies, through inadequate public relations and their lack of active support to the research and development of effective oil containment and collection systems, have contributed in a major way to their own problem.

Public Law 95-273--the National Ocean Pollution Research and Development and Monitoring Planning Act of 1978 (now the National Ocean Pollution Planning Act)--requires that the Executive Branch "establish a comprehensive 5-year plan for Federal ocean pollution research and development and monitoring programs in order to provide planning for, coordination of, and dissemination of information with respect to such programs within the Federal government." The Act designates the Administrator of NOAA as responsible for the preparation of the Plan. This Plan, first issued in August 1979 is currently being revised for reissue by summer 1981 in accordance with the provision of the Act requiring bi-annual updating of the Plan. The August 1979 report and the 1980 regional conferences convened by NOAA to initiate the Plan update have identified oil spill clean-up and response and the assessment of the impacts of oil pollution as high priority needs for Federal action.

The current status of containment and cleanup capabilities inshore, i.e., in ports and harbors, is generally good. The booms, collectors, skimmers, and recovery devices are well developed, reasonably effective and efficient, and available in all major ports or areas of high spill probability. A small but significant maritime-based industry for the development and manufacture of equipment and for cleanup services has evolved. This will remain an important part of the U.S. maritime industry at essentially the same capability and capacity for the balance of the century.

There will always be important opportunities for effective new systems to enter this market. The maritime industry should be inovative relative to the inshore, port, and harbor areas.

There is another, more important area--offshore coastal waters and the open ocean--where containment and cleanup capabilities are extremely limited and where little if any significant research and development is taking place. The conventional boom and skimmer techniques are limited to currents of 1 knot or less and sea states of about 3 or less.

Efforts to develop high-seas oil containment and recovery technology or techniques have received little support by the U.S. Government and essentially no support by the offshore and oil industries. This national need, cited by several congressional hearings on fisheries and offshore development, is one that the U.S. maritime industry could respond to and benefit from, given proper and adequate U.S. policy and support.

Three specific opportunities are identified for the maritime industry as follows:

Multipurpose Vehicles: Cleanup vehicles are expensive to maintain and to operate if they are used only for cleanup services. World Dredging magazine of April 1979 reports that IHC Holland has a combined oil-spill cleanup/hopper dredge vessel on their drawing boards.[25] Available on a 24-hour call basis, the dredge could be rapidly converted by the crew to function as an oil cleanup ship. The design calls for a 50-yard (45.7-m)-wide sweep path, and the ship's hopper capacity of 5000 cubic meters could store 1,000,000 gallons (3,785,000 liters) of oil pending the arrival of tankers or barges for offloading. The committee believes that such innovation should be encouraged and supported by both the U.S. Government and the offshore industry. This dual-purpose dredge concept could be applied, by conversion, to existing hopper dredges of the U.S. Army Corps of Engineers.

Innovative designs could probably convert some of the offshore service fleet to multipurpose vehicles capable of responding almost immediately to major spill incidents with essentially no loss in the basic capability for which designed. Other ships that could be designed to provide dual services are fishing trawlers, Coast Guard buoy tenders, Navy salvage vessels, and small to medium-sized U.S. flag tankers.

High-Seas Containment Systems: These need to be effective in currents of 2 or even 3 knots and should be operable in sea states up to 6 in order to assure operability in the majority of weather in coastal spill areas. The recently announced Air Jet Oil Boom by Hydronautics, Inc.,[26] is an example of the type of innovation and R&D that is needed and that must be supported by both the government and industry.

Sweep systems and towing vessels that can maneuver at near zero speed suggest possible ship designs using a cycloidal propeller similar to the particularly maneuverable German-built small-tug design. The loss in propulsion efficiency is fully compensated for by maneuvering and control capabilities. The Soviet Union has a major program to develop such systems for the Black Sea and Crimean Sea, and their operating equipment is reported to be extremely effective.[23]

Arctic Areas: The most difficult oil-spill cleanup area will be the Arctic, where, except for some excellent work by the U.S. Coast Guard, virtually no research and development effort has been made. This element coupled with opportunities for development and production of Arctic petroleum resources could become a controlling factor relative to environmental concerns and public pressures. The Oil and Gas Panel of the 1976 National Planning Conference on the Commercial Development of the Oceans also cited this as a high-priority national need and recommended major federal R&D support "to determine and develop

techniques suitable for securing and retrieving oil spills in Arctic environment"[21] leading to the actual construction and test of new equipment and systems.

Pipe Laying and Trenching

The basic technology developed on the calm waters offshore Louisiana and Texas has been brought to full maturity as a sophisticated industry capable of operating in heavy weather by the North Sea experience of recent years. It is now moving into deepwater operations by the development of such new vessels as the $150 million semisubmersible, CASTORO SEI, which has already set the world's record by completing three pipelines in 1200 ft (365 m) of water across the Straits of Messina. It is scheduled to reach a new record by laying three 20-inch (50-cm) diameter gas pipelines from Sicily to Tunisia, a distance of 100 mi (160kmi) at maximum water depths of 2000 ft (609 m).

Reel systems, using designs for both vertical and horizontal reels, have increased continuous pipe-laying capabilities to as much as 50 miles (80 km) for 4-in. (10-cm) pipe. Trenching systems to bury pipes in the seafloor have become equally advanced and sophisticated as demonstrated by requirement for burying the entire Stratfjord field pipeline to Norway including the crossing of the Norwegian Trench at a depth of 1150 ft (350 m).

As U.S. offshore exploration and development increases over the next 20 years there will be some increased need for additional pipe-laying and pipe-trenching vessels. The technology already exists, and the vessel types used in the North Sea environment are projected to meet the service requirements of the offshore industry for both the Atlantic and Pacific continental shelf areas.

The development of U.S. Arctic regions will require new vessels and technologies to work in that cold and ice environment. However, the Norwegian developments moving north of 60 deg latitude will probably lead U.S. Arctic developments.

There remains, however, an important opportunity for the U.S. maritime industry to design and build innovative pipe-laying and pipe-burying systems for very deep water and for Arctic areas.

Manpower

One of the most critical needs of the offshore industry is trained and motivated manpower. Leonard Leblanc, news editor, in the January 1979 issue of Offshore, sets forth in dramatic terms the high demand for skilled labor and the devastating effect of turnover rates reaching 500 percent per year in some limited operating skills and areas.[27] While this is not an opportunity directly related to the U.S. maritime

industry, it does represent an opportunity for supporting interests in worker training, education, and motivation.

Maritime industry training schools could provide an invaluable service to the offshore industry and reap significant benefits in return by responding to this serious and costly manpower problem.

Post-Petroleum Production Uses of Offshore Structures

In the Gulf of Mexico today, when a field has been depleted, the production platforms and other equipment must be removed with nothing remaining to evidence their one-time existence for several feet below the mudline of the Gulf floor. The answer to what can be done about these structures through alternative uses represents a significant opportunity for the U.S. maritime industry over the next 20 years as more and more wells cease production.

Consideration should be given to conversion or utilization of such structures. Given such resources, there are many areas in which the U.S. maritime industry could contribute. Some suggested uses for these structures include the following:

- Recreational facilities, offshore resorts for fishing, sailing, and diving;
- Industrial processing plants for hazardous operations such as LNG and chemicals, to remove the plants from population centers and service such centers through pipeline systems;
- Low-energy process systems, where wave and/or wind power would make the facility energy independent;
- Energy-generating platforms for wind, wave and solar-energy devices;
- Fish-processing operation to freeze and package fish products with minimum transportation time and thereby provide a better return to the fishing industry;
- Navigational aids and ship traffic control stations; and
- Emergency rescue and refuge facilities.

Under existing regulations, the production platform owner is responsible for removal of the structure to below the mudline when the structure is abandoned. Therefore, such uses of surplus structures as listed above could involve the assumption of responsibilities for platform maintenance and ultimate disposal. Those costs should be considered in planning the overall project funding.

Findings and Conclusions

Based on the foregoing analysis, estimates, forecasts, and guesses, the committee believes there are specific actions, policies, and conditions that will greatly facilitate response by and enhance the benefit to the U.S. maritime industry from the offshore oil and gas opportunities identified.

Offshore Drilling Rigs and Platforms

The strongest market potential is in the fabrication of jack-up, fixed platform, and submersible rigs, and this is entirely dependent on a rapidly expanding offshore exploration and development effort. In contrast to some other studies and forecasts, the committee concluded that the average U.S. production forecast of about 35 rigs per year is within the capability of existing shipyard and fabrication facilities, and it represents a potential full utilization prospect for the next 10 to 20 years. At the current average prices, this is a market potential of about $700 million per year in new or replacement rig construction. Steel demands will be high, and U.S. suppliers should consider this potential demand.

There is no new or sophisticated technology required for the offshore industry to operate effectively and efficiently in the U.S. continental shelf areas for the next 10 to 20 years. The key to this opportunity will be a strong U.S. energy policy and a national commitment to full and rapid exploration and development of the potential U.S. offshore resources.

Deepwater technology both in the drilling rigs and production systems including seafloor completion are under active development by the offshore industry. These will be available when justified by the economics of deepwater operations. The maritime industry must stay abreast of these developments and plan now for future construction and support opportunities.

Support/Service Vehicles

The demand for increased support/service vehicles attendant to increased offshore development represents a significant ship/boat building opportunity that is well within the capability of the existing industry facilities. The volume of construction is estimated from 250 to 350 vessels per year at a value of $500 million to $1000 million. A substantially increased rate of offshore development with an attendant increased demand for support/service vessels is not expected to cause a boat or small-ship building overload for the U.S. maritime industry.

Arctic/Ice Technology and Transportation

Major R&D support for Arctic/ice technology and transportation by both government and industry is required to facilitate development in the Arctic and Alaskan shelf areas. Subjects of high priority are ship and platform technology--structures and materials development; ice-breaking technology to be able to operate safely and to maintain open areas in the ice environment; iceberg/iceflow control systems; and submersible/subsea systems for operation and transportation. Based on the report of the National Planning Conference on the Commercial Development of the Oceans,[22] and on the Society of Naval Architects and Marine Engineers, T and R Report R-26, "High Priority Research for the U.S. Maritime Industry,"[21] there is a national need to invest $25 million to $50 million over the next 5 to 8 years in applied Arctic R&D efforts.

Special Support Systems for Deepwater Operations

The existing marine service industry producing and providing both manned submersibles and unmanned remotely operated vehicles (ROV's) is considered capable of providing the projected service demands of the offshore industry. This is a rapidly growing field where innovation can have a large return. According to <u>Offshore Industry</u>, August 1978,[28] the unmanned submersible fleet employed by the offshore oil and gas operations has expanded by 70 percent last year; and <u>Offshore Industry</u>, August 1979[29] reports a 36 percent expansion this year. As technology is developed and operations go deeper, a more rapid growth is forecast. Already the offshore service industry is estimated to have a total investment of about $100 million in ROV's. It is expected that an annual growth rate of from 20 to 50 percent will occur during the 1980's, depending on the rate of deepwater and Arctic development worldwide.

The current R&D efforts by industry and government agencies, including the Navy, USGS, and NOAA, to develop unmanned, untethered robots represents a major opportunity for the U.S. maritime industry.

Pollution Containment and Collection Systems

The development of an effective national system and equipment for effective coastal and ocean oil-spill containment is urgently required. More regulation of offshore industry activity will increase the need for effective equipment and a national response system. This depends on increased federal R&D support and an effective national energy policy. R&D support of $12 million to $50 million over the next 5 to 8 years has been recommended by such studies as the "National Planning Conference on Commercial Development of the Oceans".[22]

Innovations in dual or multipurpose vessels represent a straightforward design and marketing opportunity for the maritime industry.

Improved public image through effective R&D support by the offshore industry and major oil companies could help a great deal to overcome the public's negative attitude toward expanded offshore development.

The service industry that provides cleanup services to port and harbor, inshore, and river areas is reasonably effective but offers opportunities for innovative new equipment and systems.

Arctic containment and cleanup systems depend on greatly expanded government and oil-industry supported R&D programs.

Post-Petroleum-Production Uses

Government and industry should jointly support the R&D necessary to develop uses for offshore platforms after petroleum production ceases as an alternative to the cost of removal in accordance with existing regulations.

National Ocean Structures Test and Research Program

To support environmentally sound offshore facilities and resource development, establishment of an ocean structure test and research organization and facility, including a branch dedicated to Arctic/cold-weather research, is strongly recommended. The primary objectives for the organization should include the following:

- Collection of environmental data of wind, wave, and ice forces to improve the design of offshore structures;
- Development of innovative systems and equipment for all phases of offshore operations;
- Field testing of advanced equipment and technology, and demonstration of the feasibility and practicability of controls and regulations before their implementation.

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CHAPTER 3
ENERGY

Overview

For centuries men have used the sea not only as an avenue for trade and communications and as a source of food but also as a source of energy. Tidal currents have powered mills in ancient Greece, medieval Europe, and colonial America. The vast energy of motion and the remarkable differences in heat content within the water column of the sea can do useful work with little resulting pollution; and it is renewable. The source is sustained by solar energy, with secondary inputs by the gravitational fields of the moon and the sun, and by the rotation of the earth. Thus as traditional sources of energy become depleted and interest increases in alternate sources, especially those that are renewable, men have turned to the sea. Devices are being proposed, or are in development, to harness the energy of ocean thermal differences, waves, currents, tides, winds, and salinity differences. Experiments also are being conducted to derive renewable energy from plants grown in the sea (biomass). The disadvantage, however, of ocean energy is its great dispersion--so that efficient conversion to a useful form is possible only in limited locations of special concentration. This chapter examines the availability of the several resources, the technologies to effect their recovery, constraints against and incentives for the development of those technologies, potential benefits to the United States in their development, and opportunities that such development will create for the U.S. maritime industry within the time frame of this study, 1980-1990. It will be seen that few of the proposed systems will meet the test for significant contribution in the next decade.

The oceans also are a source of such nonrenewable energy resources as offshore gas and oil, offshore geothermal energy, and offshore hard minerals such as coal and oil shale. Offshore gas and oil is treated separately in Chapter 2.

Table 6 lists all ocean energy resources on the common basis of potential in megawatts (MW), where 1 MW = 1000 kilowatts (kW) or 1,000,000 watts (W). Nonrenewable resources are shown both in terms of currently estimated total reserves and in terms of availability if

TABLE 6 Ocean Energy Potential

PART 1 - TOTAL ESTIMATED OCEAN ENERGY RESOURCES

TYPE	TOTAL POTENTIAL	CURRENT UTILIZATION
Ocean thermal Conversion	10,000,000 MW	None.
Ocean wave power	500,000 MW	Negligible.
Ocean current power	50,000 MW	None.
Ocean tidal power	200,000 MW	248 MW.
Ocean wind power	170,000 MW (United States)	Negligible.
Salinity gradient power	3,540,000 MW	None.
Ocean bioconversion	770,000 MW	Negligible.
Continental Shelf oil reserves	172,800,000,000 bbls.	3,296,000,000 bbls./year.
Continental Shelf oil resources	520,000,000,000 bbls.	
Continental Shelf gas reserves	168,500,000,000,000 ft^3	9,532,000,000,000 ft^3/year
Continental Shelf gas resources	2,693,300,000,000,000 ft^3	
Offshore geopressured geothermal energy	3,000,000 MW (United States)	None.
Offshore coal resources	508,300,000,000 tons	33,500,000 tons/year.
Offshore oil shale resources	1,000,000,000,000 bbls. (oil)	None.
Offshore tar sands resources	200,000,000,000 bbls. (oil)	Do.
Offshore uranium resources	29,400,000,000 g U^{235}	Do.

Note: The United States consumes over 6,000,000,000 bbls. of oil and about 21,000,000,000,000 ft^3 of gas per year.

PART 2 - TOTAL ESTIMATED OCEAN POWER IN MEGAWATTS (Based on 1 year's utilization)

TYPE	TOTAL POTENTIAL	MEGAWATTS FOR 30 YR.	CURRENT UTILIZATION
Ocean thermal conversion	10,000,000	--------	None
Ocean wave power	500,000	--------	(1)
Ocean current power	50,000	--------	None
Ocean tidal power	200,000	--------	248
Ocean wind power (United States)	170,000	--------	(1)
Salinity gradient power	3,540,000	--------	None
Ocean bioconversion	770,000	--------	(1)
Continental Shelf oil reserves	33,500,000	1,116,000	640,000
Continental Shelf oil resources	101,000,000	3,366,000	----------
Continental Shelf gas reserves	5,600,000	186,000	310,000
Continental Shelf gas resources	89,000,000	2,966,000	----------
Offshore geopressured geothermal energy (U.S.)	3,000,000	100,000	None
Offshore coal resources	499,000,000	16,633,000	32,900
Offshore oil shale resources	194,000,000	6,466,000	None
Offshore tar sand resources	38,800,000	1,293,000	None
Offshore uranium resources	77,200,000	2,573,000	None
Total	1,056,330,000	--------	983,148

(1) Negligible.

Note: Total U.S. power capability equals 2,000,000 MW. Total U.S. electrical power capability equals 440,000 Mw. Total world power capability equals 8,200,000 Mw. Projected world power capability needed in year 2000 equals 15,000,000 Mw.

Source: U.S. House of Representatives, Subcommittee on Advanced Energy Technologies of the Committee on Science and Technology. Energy From the Oceans. 95th Congress. Science Policy Research Division, Congressional Research Services, 1978.

depleted over a 30-year period. Total U.S. power capability in 1978 was estimated to be 2,000,000 MW, or 2000 gigawatts (GW), where 1 GW = 1000 MW, or 1,000,000 kW, or 1,000,000,000 W. Total world capability is 8,200,000 MW (8200 GW). Projected world requirements by the year 2000 equal 15,000,000 MW (15,000 GW).

Except as otherwise noted, facts and figures quoted in this chapter have been derived from the report of the Congressional Subcommittee on Advanced Energy Technologies, Energy from the Oceans.[1]

Thermal Energy

Between the Tropic of Cancer and the Tropic of Capricorn, where the ocean accounts for some 90 percent of the world's surface area, warm water overlies much colder water at depths that vary with latitude from 3300 feet (1000 m) near 30° N and 30° S latitude to a little more than 300 feet (100 m) near the equator (Figure 4 shows a world plot of that difference for 1000 m depth). While estimates of the thermal energy available for conversion have ranged from 100,000 GW to 10,000,000 GW, a reasonable upper limit based on environmental considerations relating to the cooling of ocean surface waters appears to be on the order of 400,000 GW.[2] At an estimated conversion efficiency of 2.5 percent, this would equate to 10,000 GW of electrical energy.

Of the world's total ocean thermal resources, 1400 GW[3] to 4000 GW[4] may ultimately be available for conversion to 35 to 100 GW (at 2.5 percent conversion efficiency) of electrical energy for direct introduction into grids of the continental United States. This would come from the Gulf of Mexico. It represents 8 to 23 percent of current U.S. electrical power-generating capability. Other areas of interest to the United States exist off Hawaii, Puerto Rico, the Virgin Islands, Guam, Micronesia, and the South Atlantic. It must be emphasized, however, that the usefulness of this energy to these areas depends not on the available energy but on the economics of the conversion process. Also, much of this energy is available at locations far at sea, where it would have to be used on site in plant ships designed for power-intensive industrial processes such as the production of ammonia, hydrogen, or aluminum.

Recovery Systems/Technology

The concept of "solar sea power" is not new, but a full- scale ocean thermal power plant has yet to be built. Most of the major work funded to date on power systems has involved the conceptual and preliminary design and evaluation of closed Rankine power cycles. The favored working fluid has been ammonia because of its high-heat-transfer properties and relatively high density at working pressure. Figure 5 is a simplified schematic of a closed ammonia cycle power system. Georges Claude used an open Rankine power cycle in which water

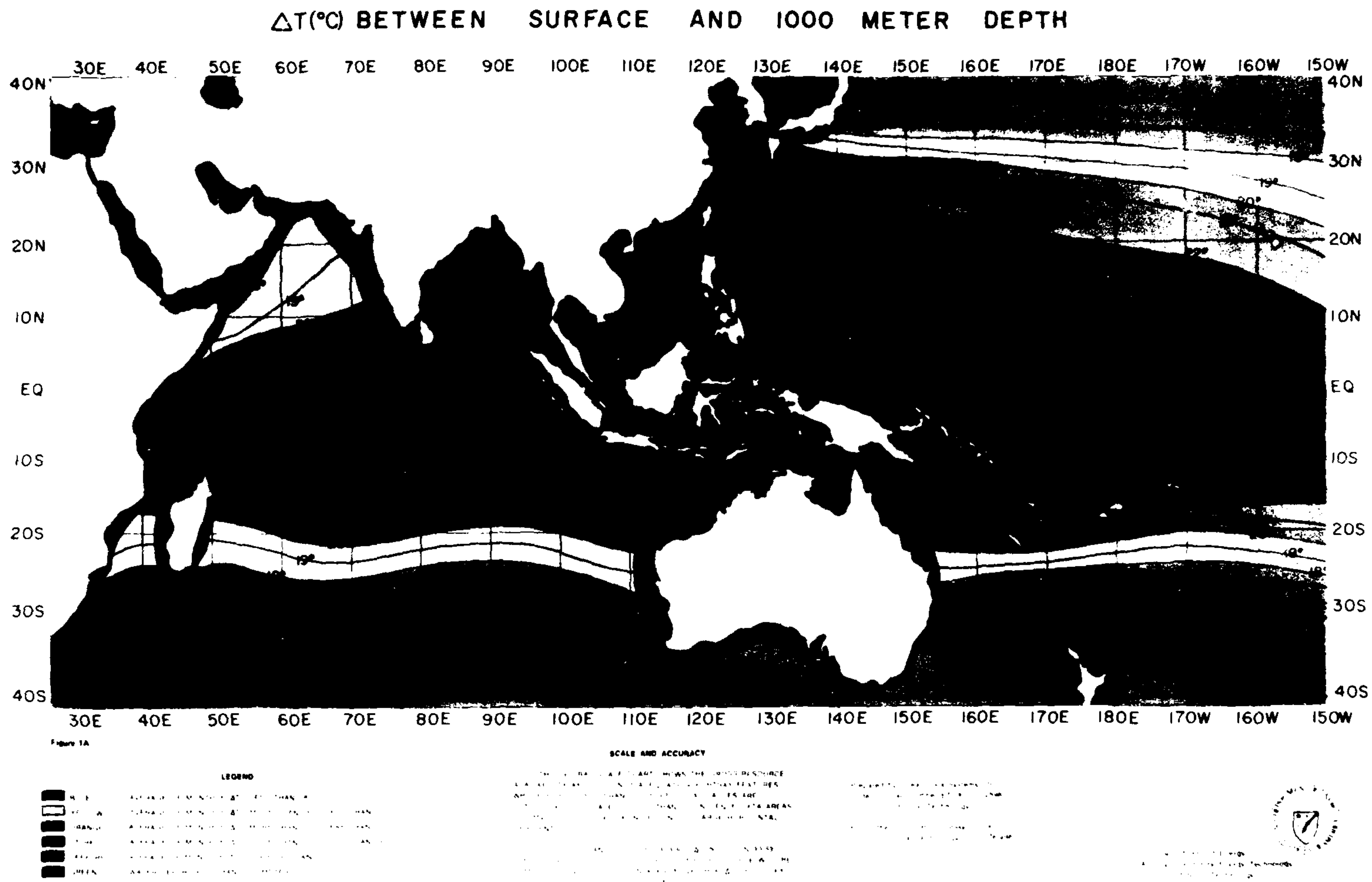


FIGURE 4 OTEC Thermal Resource

Source: U.S. Department of Energy, Division of Solar Technology

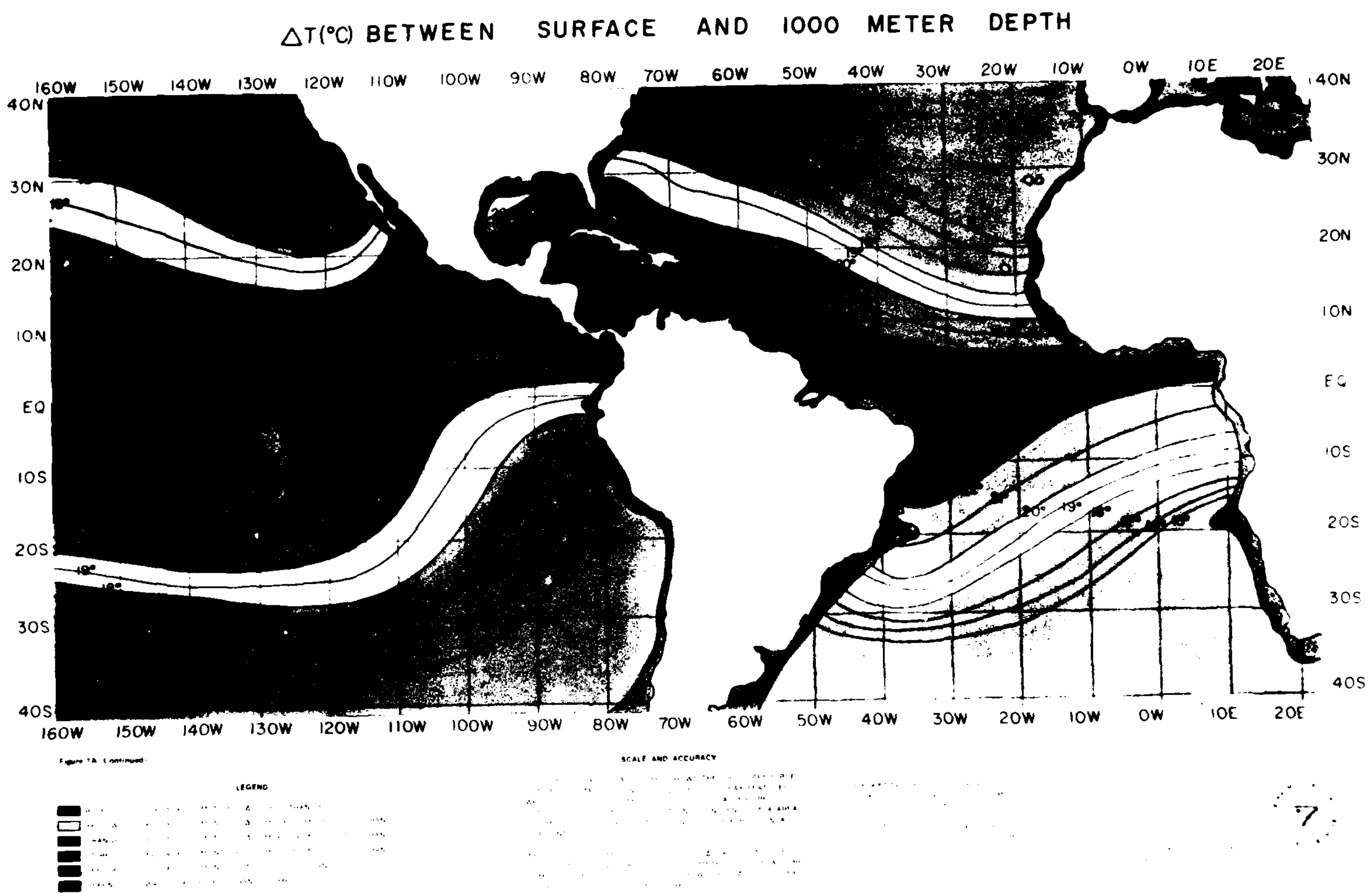


FIGURE 4 OTEC Thermal Resource (continued)

Source: U.S. Department of Energy, Division of Solar Technology

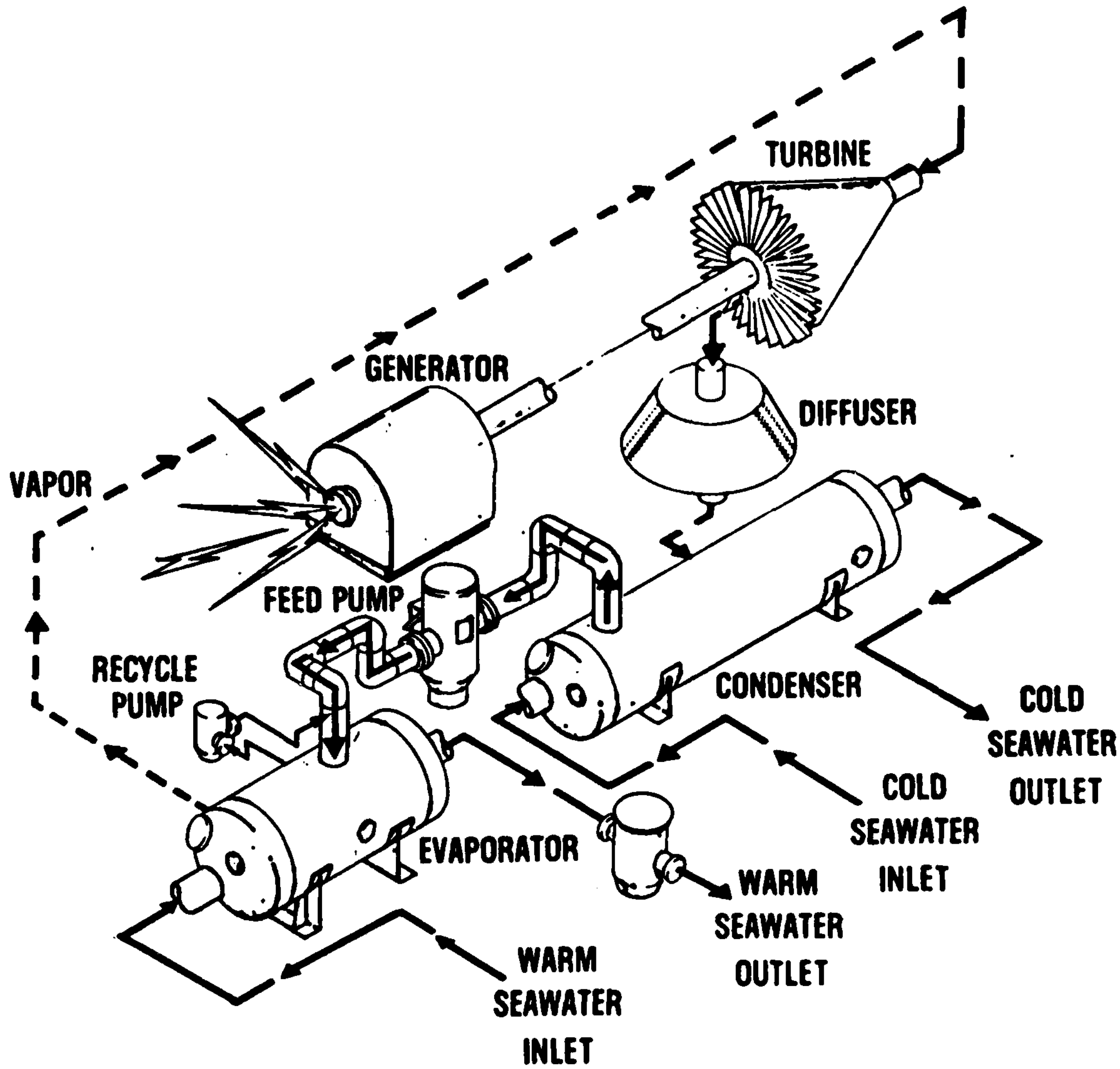


FIGURE 5 OTEC Closed Cycle Flow Diagram

Source: Westinghouse.

was the working fluid for his 1930 demonstration plant. Figure 6 is a simplified schematic of an open-cycle power system. Other open-cycle alternates such as the "foam" and "mist" cycles, Figures 7 and 8, may hold some promise but represent emerging technologies that will require considerable development work to prove whether practical.

Ocean Thermal Energy Conversion (OTEC) technology is at present being developed by the Japanese Government, the French Government, and the Association Europeene Oceanique (EUROCEAN), Monaco, as well as by the United States. The major effort is in the United States, where work was first sponsored by the National Science Foundation (NSF). The Department of Energy (DOE) OTEC technology development program is aimed at developing and testing viable OTEC components, subsystems, and systems. Activities are divided into three complementary phases: small scale, on the order of 1 MWt; large ocean test, on the order of 1 MWe (40 MWt); and pilot plant, equal to or greater than 5 MWe.[3] (MWt is the source thermal energy in megawatts of a power generation system; MWe is the output electrical power in megawatts of the system. They are related by the net conversion efficiency, which is about 2.5 percent for temperature differences of 36° F (20°C)).

The small-scale phase has primarily addressed heat- exchanger problems such as biofouling, tube cleaning, corrosion, and the thermal performance of tubes. The large ocean tests will evaluate several large scale heat exchangers (both evaporators and condensers) on the OTEC-1 Test Platform, a converted T-2 tanker (Figure 9). Evaluations will cover heat-exchanger configuration, material, working fluid, tube enhancement, and biofouling control. The tests also will give insight into problems associated with cold-water pipe deployment and service loads on a sizable [three 48-inch (120-cm) clustered pipes] model, and with deepwater mooring, 4000 feet (1200 m).

Work leading to the pilot-plant phase has included four major conceptual and preliminary design power-plant study contracts accomplished by Lockheed, TRW, Westinghouse, and the Applied Physics Laboratory (APL) of Johns Hopkins University; three platform conceptual study contracts accomplished by Lockheed, Gibbs & Cox, and M. Rosenblatt & Son; and supporting cold-water pipe, mooring, and underwater electrical power-transmission study contracts.

Under other study contracts performed for DOE, Westinghouse has developed the conceptual design of a 100- MWe open-cycle power plant, and Lockeed and Alfa-Laval currently are investigating shell-less heat exchangers. Figures 10, 11, 12, and 13 illustrate closed-cycle power-plant concepts developed by Lockheed, TRW, Westinghouse, and APL, respectively. Figure 14 is the conceptual design of a 100-MWe open-cycle power plant developed by Westinghouse.

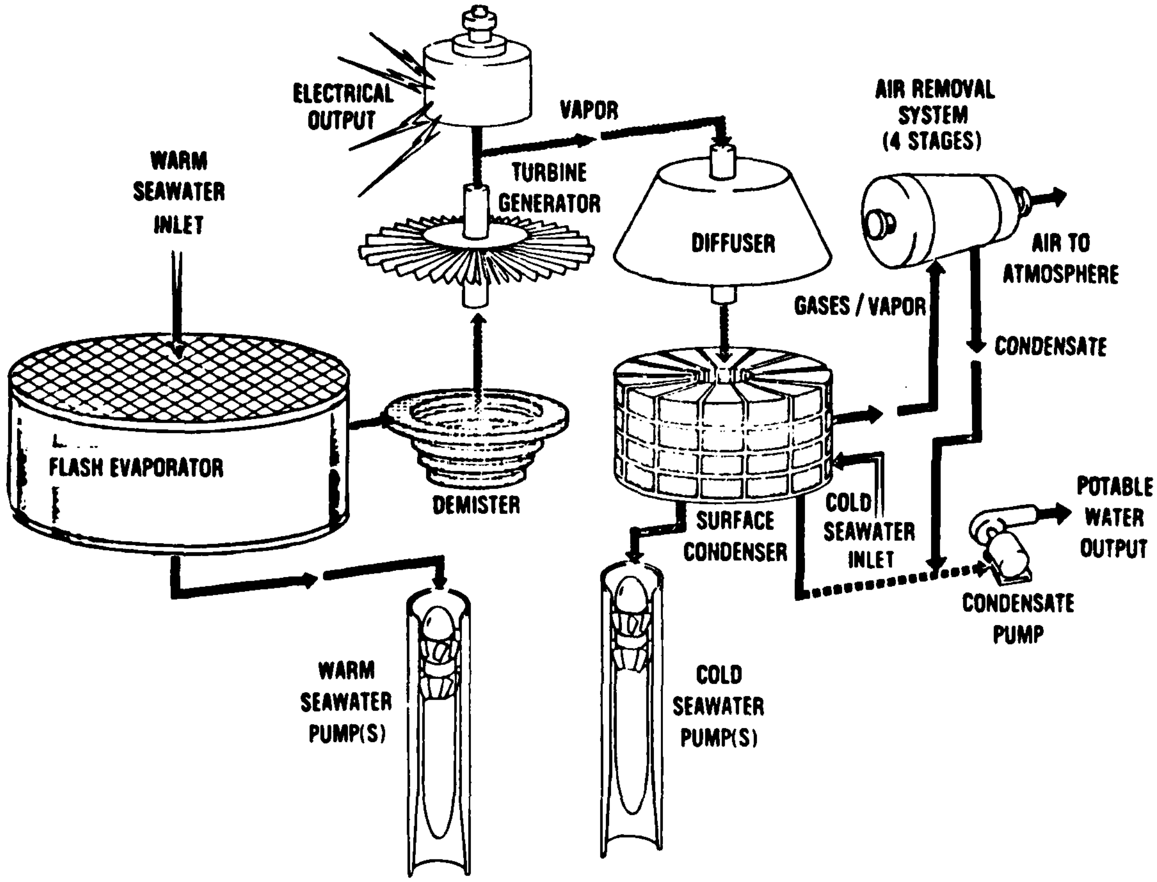


FIGURE 6 OTEC Open Cycle Flow Diagram

Source: Westinghouse.

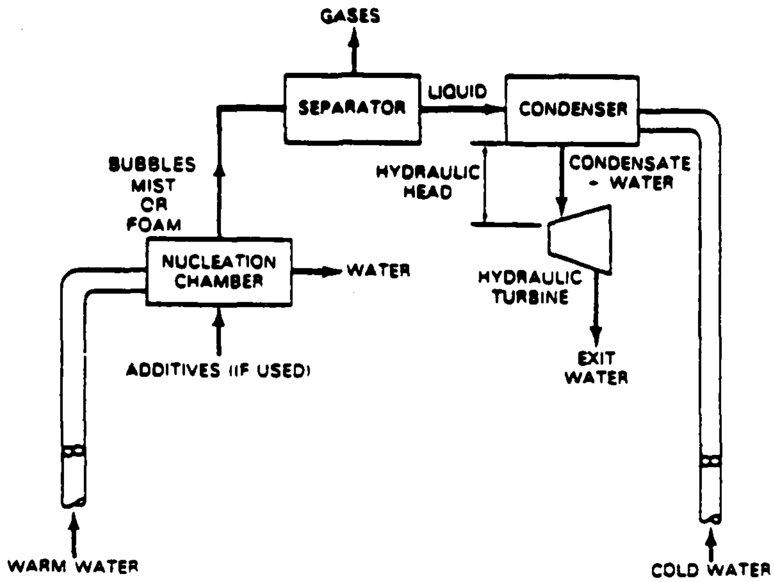


FIGURE 7 Lift-foam Cycle Schematic

Source: An Overview of the U.S. OTEC Development Program.

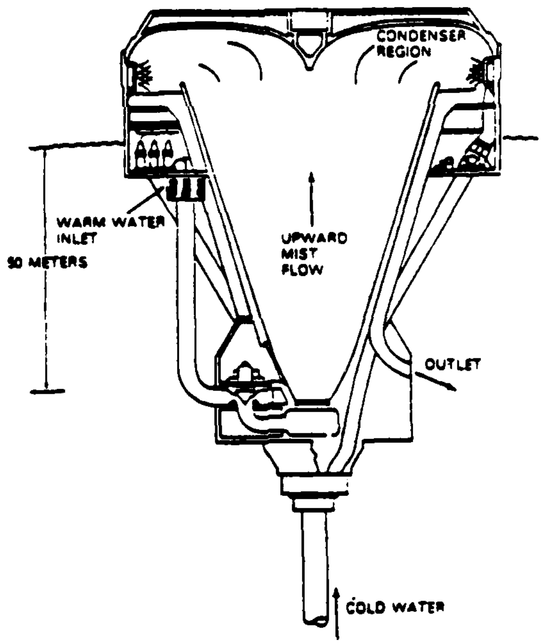


FIGURE 8 10 MWe Mist Flow Plant

Source: An Overview of the U.S. OTEC Development Program.

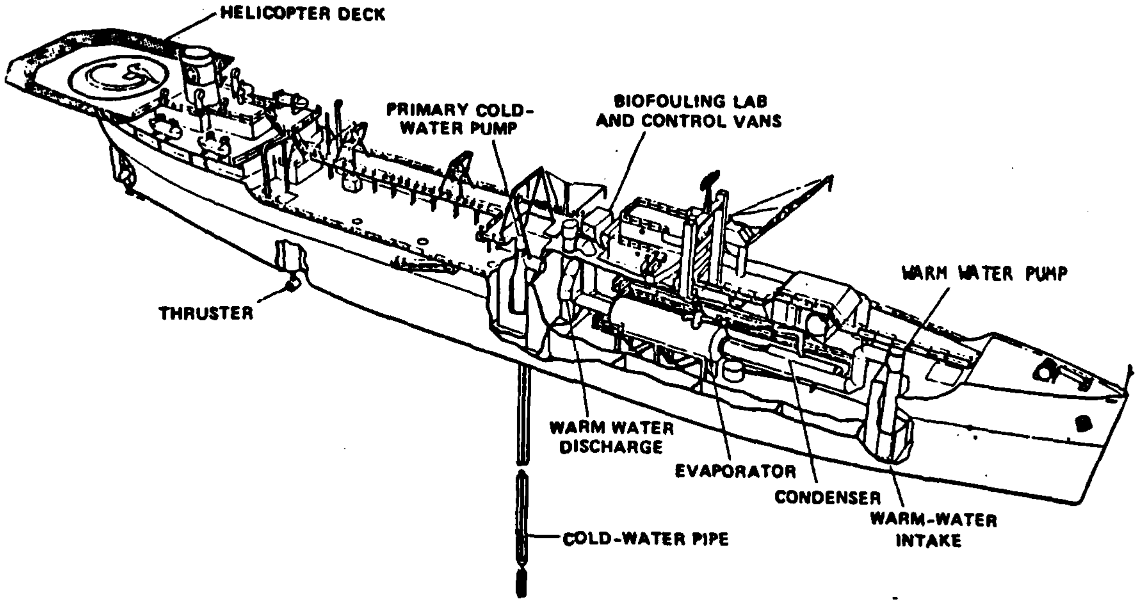


FIGURE 9 Isometric Cutaway of CHEPACHET

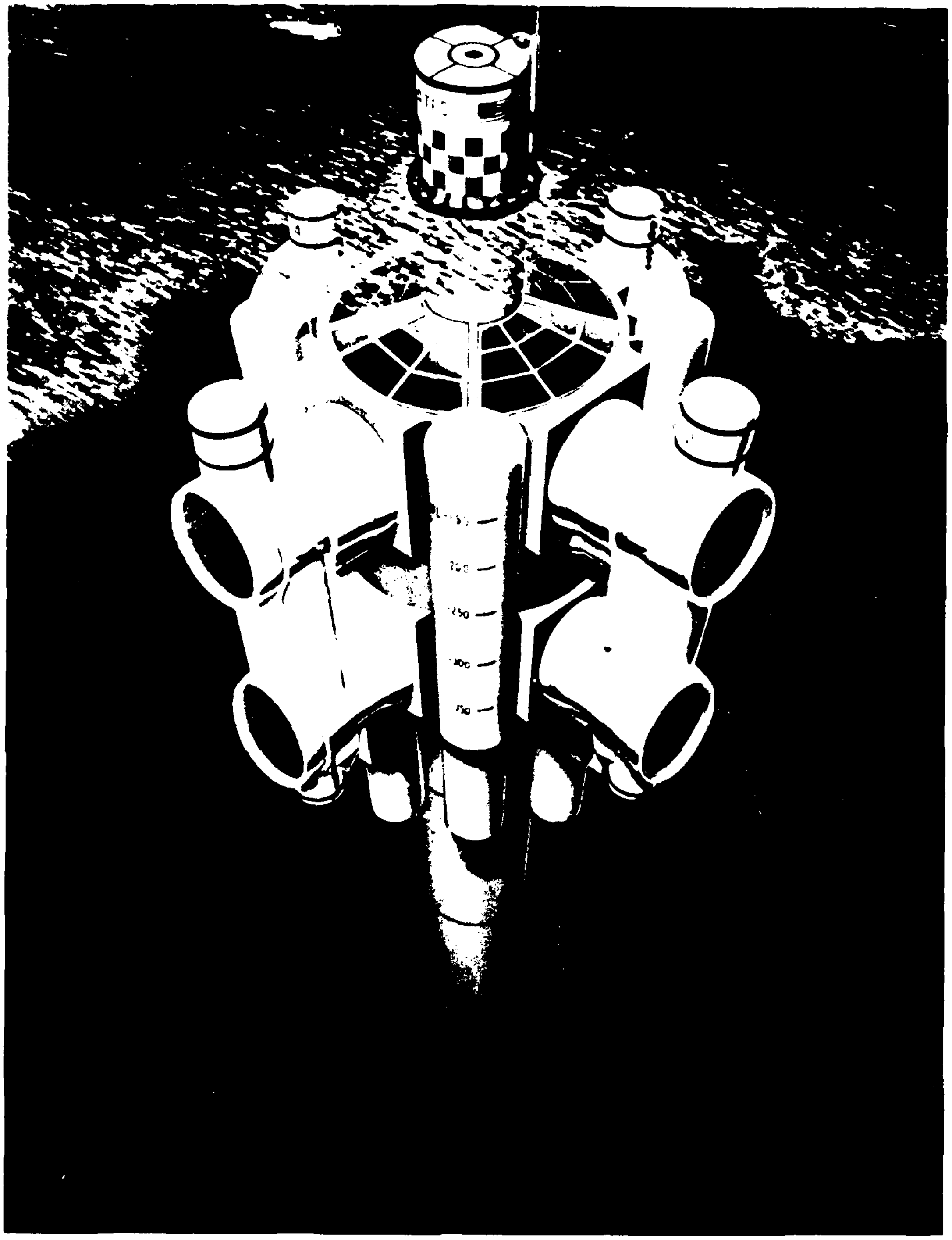


FIGURE 10 Lockheed 100 MWe OTEC Power Plant
Source: Lockheed Missiles and Space Company.

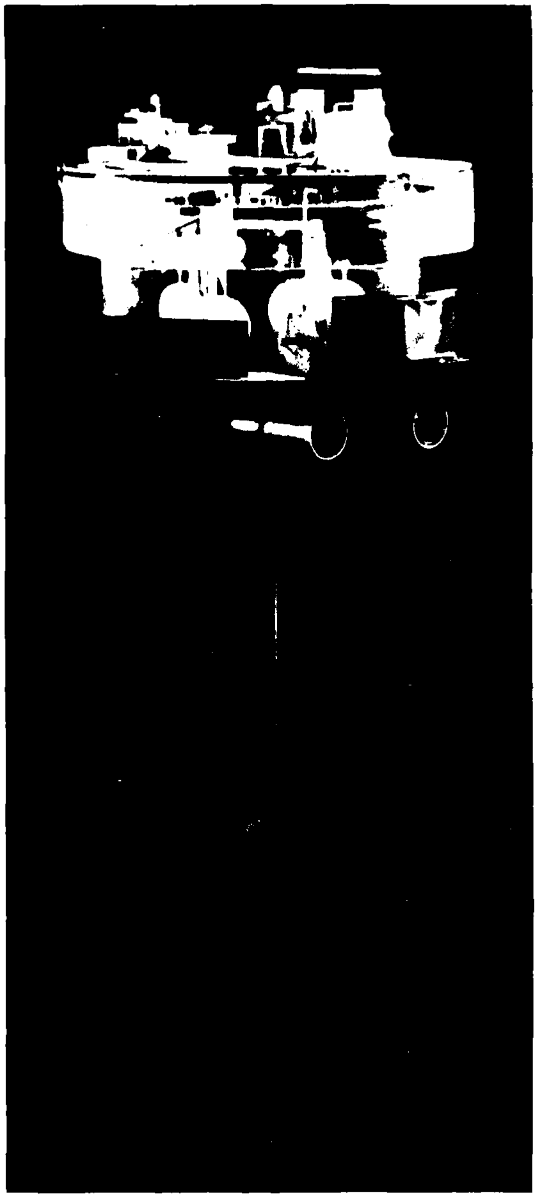


FIGURE 11 TRW 100 MWe OTEC Power Plant

Source: TRW.

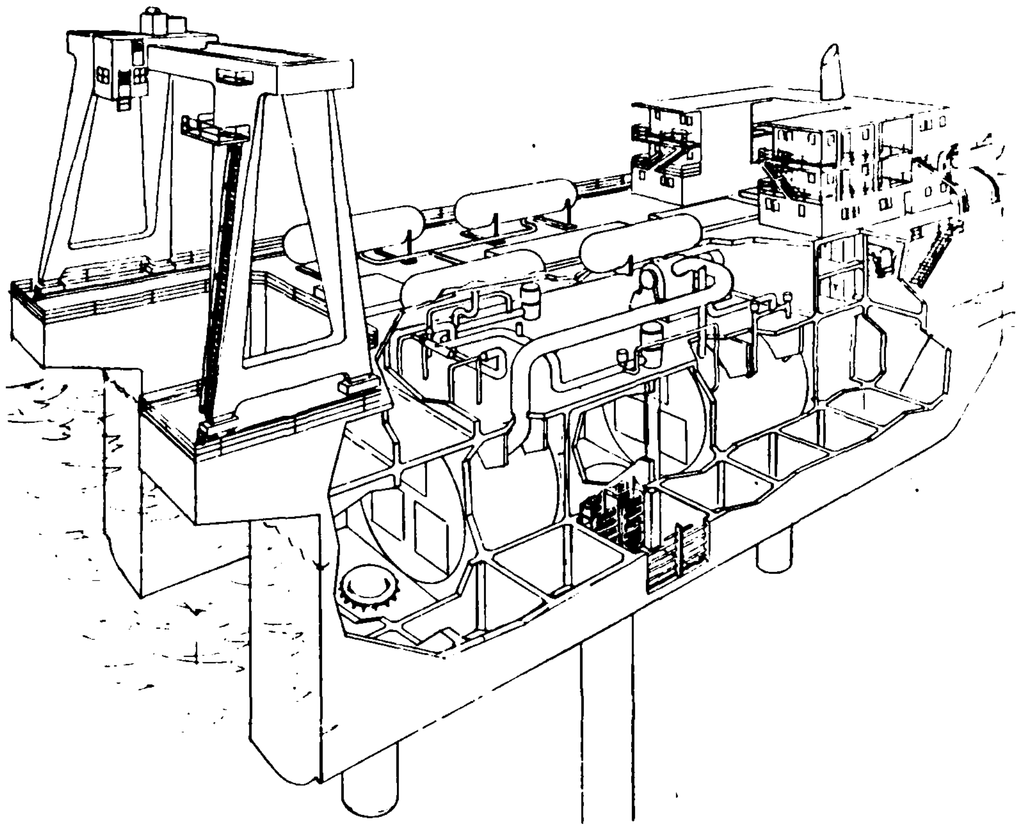


FIGURE 12 Westinghouse 10 MWe Plant/Platform

Source: Westinghouse.

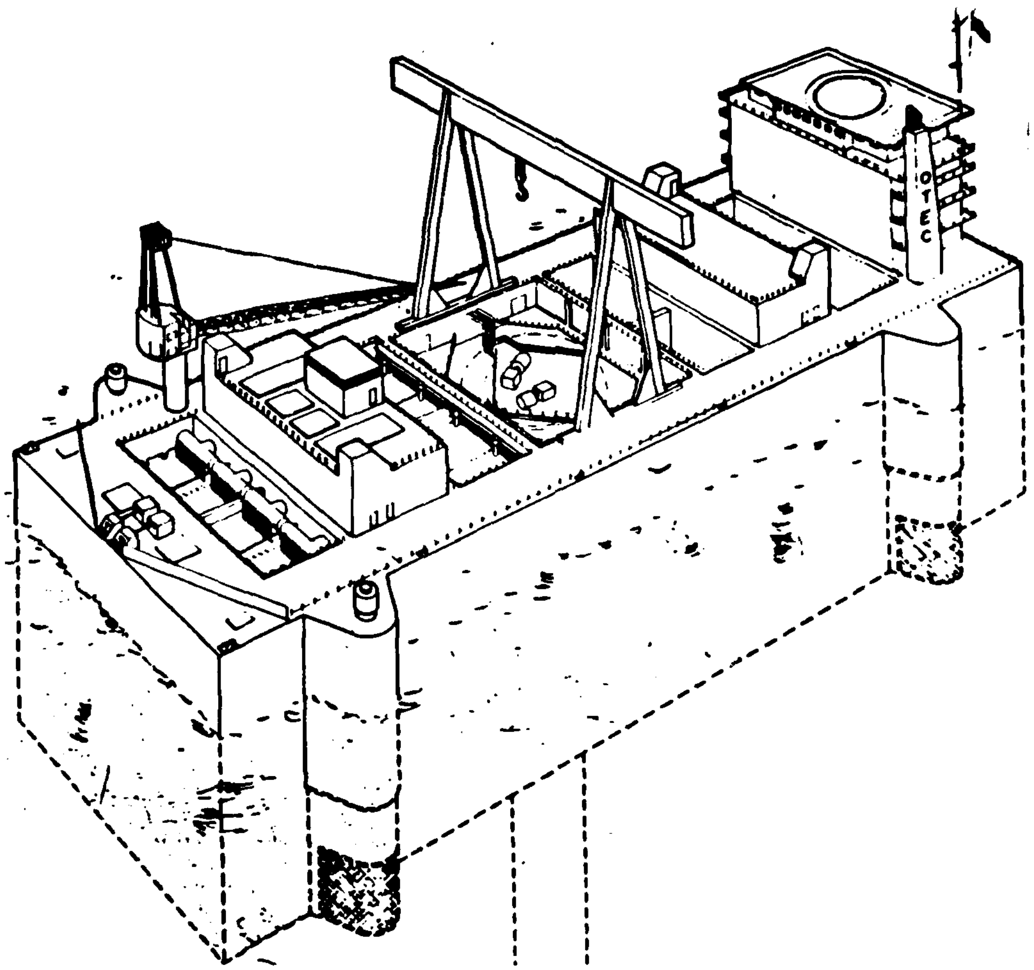
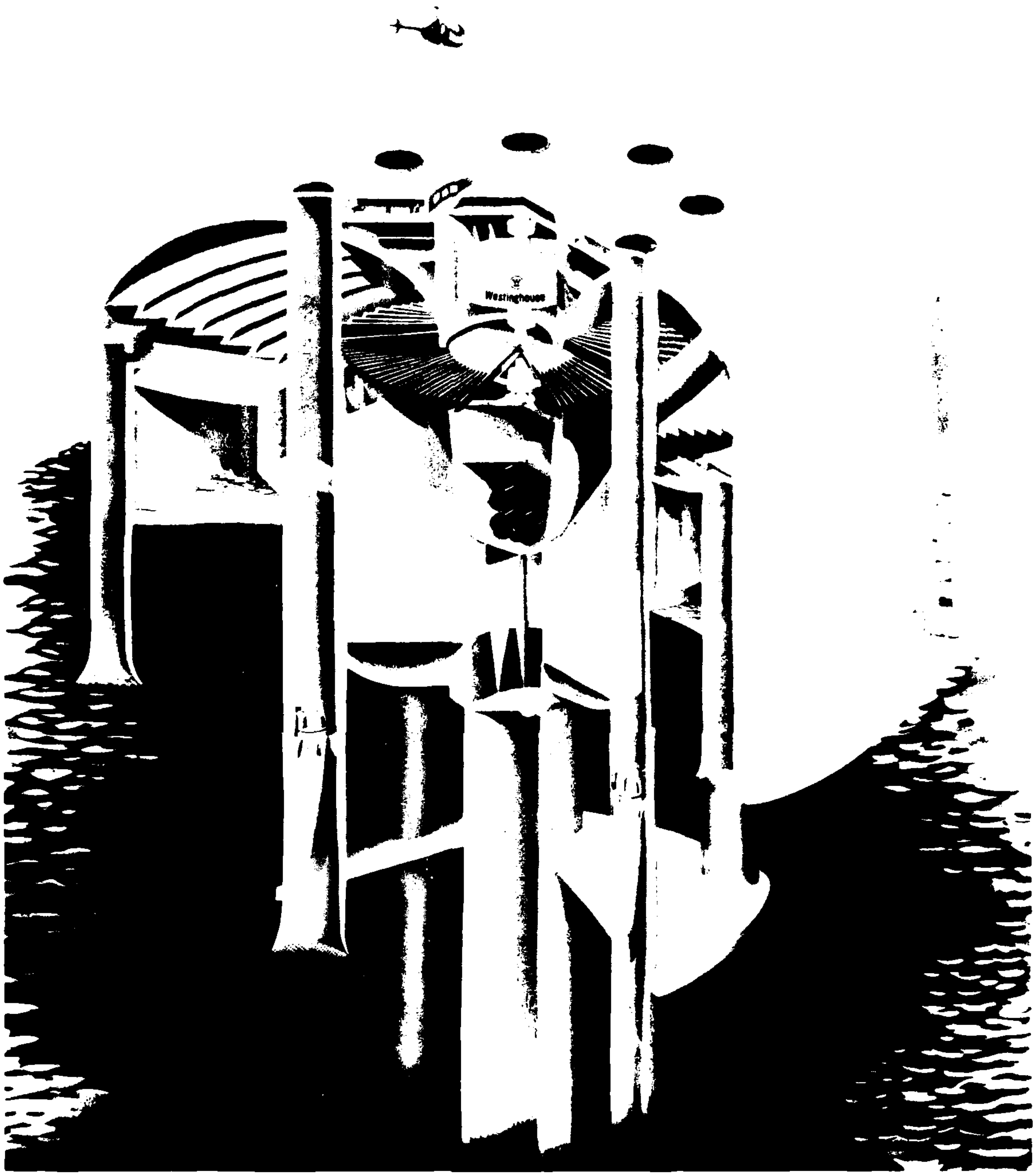


FIGURE 13 APL 5/20 MWe Power Plant

Source: Applied Physics Laboratory.



FI 'URE 14 Westinghouse 100 MWe Open Cycle OTEC Power Plant

Source: Westinghouse.

Investigations to date support a position that all elements of the power plant can be constructed in existing facilities with current technology in module sizes up to 50 MWe net output capacity.[5] A module generally has been defined as an evaporator, a turbogenerator, a condenser, and its associated seawater and working fluid-circulating pumps and piping.

It generally is considered that a practical commercial OTEC plant will consist of eight 50-MWe modules assembled on a platform to produce a total net output of 400 MWe. This compares closely with the 500- to 600-MWe output of the average new fossil-fueled power plant for a utility network and is a little more than a third of the 1100-MWe output of the average new nuclear plant.[6] Smaller plants (50 MW and up) have potential application in island and lesser developed countries.

Similarly, studies indicate that platforms with acceptable motion characteristics up to limiting operational sea states, capable of surviving storm conditions, also can be designed and built with current technology and in present-day facilities. The major technical problem areas remaining appear to be the design, construction, and survivability of the cold-water pipe, the mooring system, and the electrical transmission system. Current contracts will recommend solutions to the cold-water pipe and mooring problems. Successful solution of the submarine cable problem appears presaged by the power transmission lines that have been run between Norway and Denmark across the Danish Straits.

However, it should be carefully noted that the elements of the OTEC plant system--power plant, platform, cold-water pipe, mooring, and electrical transmission cable are each in its own right a challenging technical problem with much development and testing yet to be done. The viability of proposed technical solutions to these OTEC plant subsystems will be proven only by the deployment and operation of pilot plants at sea. The design, construction, and deployment of such units in the 10- to 40-MWe size, as planned for the early 1980's by DOE, will offer the first opportunity for the maritime industry to participate in the OTEC program to any significant extent, and will also help to answer questions that have been raised concerning climatical and ecological effects if OTEC stations were to be operated in substantial numbers.[7]

Constraints against Development

The legal status of a cable-connected OTEC plant has not been clearly defined either as a matter of national regulatory law concerning liability, safety, and the environment or as a matter of international law concerning resource control and regulatory jurisdiction. From a national regulatory standpoint, apparently one legal interpretation would classify it as a moored ship subject to the same regulation as offshore drilling platforms. Another view holds

that an umbilical to shore places the OTEC plant in the category of a fixed island. The status of an untethered plant ship is clearly that of a ship. The ambiguities raise questions relating to design, insurance, royalties, and other economic issues. An established body of law codes and standards, relating to national regulation of OTEC platforms, would significantly benefit their commercial development.

From an international legal standpoint, under current law as recognized by the United States, such resource would be subject to use by all as a high seas freedom in areas beyond the territorial sea. As international law develops, the ocean thermal resource within a 200-mile economic zone seems likely to fall under coastal state jurisidiction. Additionally, plants connected to shore by cable would also seem to fall within coastal state national regulatory competence.

While the resource is renewable, large-scale deployment of OTEC plants could limit the number of available sites within and beyond national ocean jurisdiction. Unlike the problem of seabed mining, however, uncertainties concerning national laws and regulations are likely to be more serious than those stemming from the international regime and competition for sites.

Government policy decisions affecting priorities and incentives for the development of other energy systems have affected and will affect the pursuit of OTEC development. There is much uncertainty relating to policy decisions about energy decentralization, strategic dispersal, the protection of offshore assets, and the broad issue of ocean development.

The government is supporting the development of technology leading to OTEC utilization, but to date there has been no large-scale demonstration of an OTEC plant operating and surviving at sea. It should be noted, however, that in the summer of 1979 a complete small scale "Mini OTEC" system went on line near the Kona Coast of the Island of Hawaii. The 50-kW demonstration plant is operating in 3500 feet (1050 m) of water. Reports indicate that all design parameters have been met and that it is delivering a net output of 10 kWe. The project is a joint venture of Lockheed, Alpha-Laval, the Dillingham Corporation, and the State of Hawaii.

If the federal government does not step in to own and operate OTEC systems directly, it will become necessary to motivate private and other public sector interests to raise the large amounts of capital and insurance required to construct and operate OTEC plants. This will not be possible until current investment uncertainty has been changed by successful operating experience and demonstrable economic performance of pilot plants of significant (at least 10 MWe) power capability.

Incentives for Development

Ranges of projected OTEC energy customer-costs estimated for the year 2000 in constant 1978 dollars compared with ranges of projected energy costs for baseload electricity derived from coal, oil, and uranium for U.S. Gulf Coast and island markets are shown in Figure 15. Again, however, the estimates are valid only if substantiated by experience with the construction, deployment, and operation of one or more pilot plants. Given this important reservation, the figure shows a significant economic incentive for technically successful OTEC plants, particularly in the island market.

An early agreement among the responsible government agencies designating all floating OTEC plants, whether moored and cable-connected to shore or grazing, as ships subject to maritime law, codes, standards, and other programs would eliminate the ambiguity of their status.

The question of the degree to which our national resources should be committed to OTEC depends on a balance with other energy sources, each requiring substantial financial outlays to develop and prove out new systems. If, from such a study, a national policy decision were to be made to pursue renewable energy resources vigorously, and particularly to develop ocean resources, the development of OTEC capabilities would be greatly benefited. To that end it is interesting to note that the Hawaii Public Utilities Commission already has been given power to direct public utilities to acquire new electrical energy from nonfossil sources and to set a rate at which energy, from nonfossil sources, generated by a nonutility producer, will be purchased by a public utility (AJ 102, Session Laws of Hawaii,1977, amended Chapter 269 of the Hawaii Revised Statutes). Two additional energy bills currently are before the tenth legislature of Hawaii. One directs the Public Utilities Commission to direct the public utilities to purchase power generated from nonfossil sources from producers currently willing to sell power to the public utilities (HCR 175). The other urges all state and county agencies to take appropriate affirmative actions to support the development and utilization of alternative energy sources (SCR 93).

It also should be noted that two bills were introduced in the first session of the 96th Congress just as this study was being completed: H.R. 5796 by Mr. Fuqua, and S. 1830 by Mr. Matsumaga. In essence these bills call for:

1. Demonstration by 1986 of at least 100 MWe or energy product equivalent from ocean thermal energy conversion systems;

2. Demonstration by 1989 of at least 500 MWe or energy product equivalent from ocean thermal energy conversion systems;

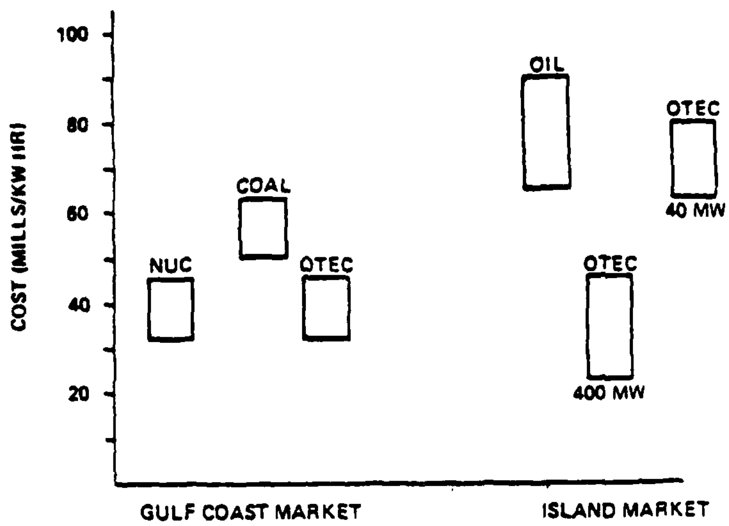


FIGURE 15 OTEC Economics

Source: Cohen, R., "An Overview of the U.S. OTEC Development Program," ASME Energy Technology Converence, Houston, Texas, November 1978.

3. Reduction by the end of fiscal year 1993 of the average cost of electricity or energy product equivalent produced by installed ocean energy conversion systems to a level competitive with conventional energy sources; and

4. Establishment as a national goal of 10,000-MWe capacity or energy product equivalent from ocean thermal energy conversion systems by the year 1999.

In addition, Mr. Studds introduced the Ocean Thermal Energy Conversion Act of 1980 (H.R. 6154), which contains provisions for financing OTEC plants and plant ships. These include Title XI Ship Mortgage insurance; use of the Capital Construction Fund program; and U.S. documentation for OTEC facilities, plant ships, and vessels to transport the ouput of OTEC plants.

Federal support of OTEC development has increased substantially throughout the years since it began in 1972. Prior to 1979, the annual support exceeded the sum of all years' previous support. It appears to have peaked however in 1980 at $43 million with the FY 81 Reagan budget request at $34.6 million. As noted above, it will require significant increases to the order of $100 million to $150 million in this funding leading to the early design, construction, operation, and evaluation of an experimental or pilot OTEC plant of at least 10 MWe net capacity before the technical and economic credibility of ocean thermal energy conversion can be assured.

Financial incentives that could help commercial development of OTEC plants include the development of split ownership arrangements with one owner/operator investing in the platform and other owner/operators investing in the power modules to spread the risk, or large consortia might be formed of potential builders and operators. Government aids might include special tax programs, loan guarantees, insurance guarantees, low-cost leasing of national assets, and federal cost sharing. Also, Federal ownership of plants, as with the Tennessee Valley Authority, might be a reasonable approach in view of the economic risks involved.

Maritime Industry Opportunities

Early goals of OTEC proponents would have provided from 10 to 50 operational commercial plants by the mid-1990's. One estimate reported that the construction of 21 commercial size OTEC ammonia plant ships by 1986 would have provided 101,000 new jobs in U.S. shipyards and would have provided 1600 new U.S. flag shipping jobs.[1] The emerging reality is far different.

One or two 10-40-MWe pilot plants are now being planned for design, construction, and deployment according to the best information available from DOE. However, the earliest possible deployment date

would be 1983. A more likely timetable would place the earliest deployment in late 1984 or in 1985. Assuming that the preliminary design, detailed design, and construction of a prototype 400-MW commercial plant would take five to six years, and that detailed design would not be likely to commence until after deployment of a pilot plant, it is unlikely that series production of commercial plants would commence before 1990. Thus, following an optimistic schedule, in the early 1990's as many as four to six 400 MWe commercial plants might be under construction at a time. This is consistent with Lockheed production studies, and with Westinghouse plans for the production of offshore nuclear power plants.[5] Such a schedule, which assumes the "best case" will have only modest impact on the maritime industry as defined for this study within the time frame addressed.

Using Maritime Administration shipyard productivity figures for the erection of steel and the installation of machinery[8] and hull-weight estimates from a Westinghouse study,[5] the following shipyard manpower requirements have been developed:

(a) For the production of two 10-MWe pilot OTEC plants in the early to middle 1980's approximately 270 men per day would be employed.

(b) For the production of up to six 400-MWe commercial OTEC plants at a time commencing in the early 1990's approximately 8500 to 11,000 men per day would be employed.

Based on cost data from References 5 and 8 it is estimated that each 10-MWe OTEC pilot plant will cost $80 million to $90 million to design, construct, and deploy. Of that total, platform cost will be $10 million to $13 million and power plant cost will be $17 million to $22 million. Deployment, which also will employ segments of the maritime industry, will cost an estimated $22 million.

Total system cost of 400-MWe commercial OTEC power plants is projected to be in the order of $700 million to $780 million for Gulf Coast plants.[4] Of this total, approximately $440 million to $520 million is for the power plant and $90 million to $170 million is for the platform, depending on the choice of hull structural material.

It should be noted that the platform studies earlier referred to, show possible cost advantages in the use of posttensioned, reinforced concrete for OTEC platforms. Dr. Cohen indicates a cost of $225/kW for a 400-MWe concrete platform based on 50-MWe power modules and $428/kW for steel.[4] Mr. McGowan indicates a range of $112.5 to $312.5/kW for 40-MWe concrete platforms and a range of $275 to $338/kW for steel.[8] Should more detailed studies confirm the advantage of reinforced concrete platforms for OTEC plants, some of the traditional shipbuilding trades would not be employed. However, the sophisticated construction techniques now being introduced from Europe will employ as much as 400 pounds (181 kg) of steel per cubic yard of concrete.

Potential Benefits

Studies have shown the availability of significant ocean thermal energy resources to the United States both as a source for direct electrical power to its distribution grids and to provide an alternative power source for process industries. Again, the caution appropriate to the early stage of system development must be borne in mind; but if current technical and economic optimism is proven by large-scale total systems experiments, estimates indicate that a range of 8 to 23 percent of continental U.S. base-load electric needs, and virtually all of the base-load requirements of the U.S. islands (Hawaii, Puerto Rico, the Virgin Islands, and Guam) could be met by ocean thermal energy in the twenty-first century.[3,4]

Wave Energy

The total wave energy contained in the oceans is estimated to be renewed and dissipated at the continuing average rate of 1 million to 10 million MW. However, only a fraction of it can be transformed for use because of its diffuse distribution. The wave conditions along the coasts of North America vary considerably by season and by geographic location. The shores of the Pacific Northwest demonstrate on average the most severe wave conditions along the continental United States. Using wave-height and wave-period data from the U.S. Army, McCormick has estimated monthly values of coastal wave power for five coastal regions of the United States.[1] The results of his work are shown in Figure 16. Values range from a maximum of 24-26 MW of crest for each kilometer of wave-length (MW/km) along the Washington-Oregon coast during the winter months to a minimum of 0.3 MW/km along the Gulf Coast during summer months. Waves approaching the Hawaiian Islands are estimated to have 23 MW/km.

The United Kingdom has perhaps the world's most advantageous coastline for wave power. Based upon measurements and calculations, the U.K. Department of Energy estimates that the average annual power, depending on location, ranges from 40 to 70 MW/km of crest length. Moreover, the seasonal variation is such that the increased wave energy due to persistent winter storms coincides with the increased winter demand for electricity. M. Y. Masuda of the Japanese Marine Science and Technology Center (JAMSTEC) has estimated that a power level of 60 MW/km of wave crest will result from the typical 12 m/sec (40 ft/sec) winter winds off the coast of Japan.[9]

Recovery Systems/Technology

Ocean wave-energy extraction is not a new concept. A large number of devices have been proposed and tested to convert wave energy into useful work. They range in size and complexity from "wave motors" to power whistles and lights on navigational buoys to large installations

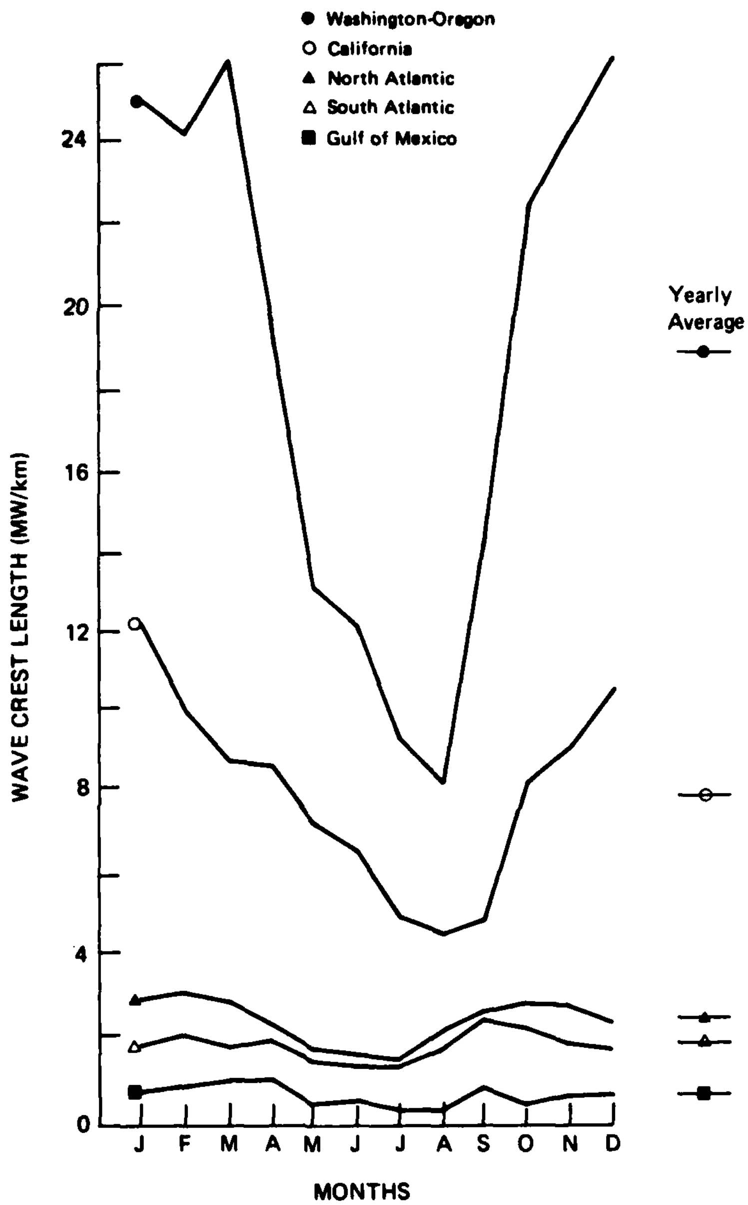


FIGURE 16 Monthly Values of Coastal Wave Power

Source: U.S. House of Representatives, Subcommittee on Advanced Energy Technologies of the Committee on Science and Technology. Energy from the Oceans, 95th Congress. Science Policy Research Division, Congressional Research Services, 1978.

intended either to contribute significantly or to augment other sources of power for man's needs. Sixty-one U.S. patents have been issued between 1876 and 1972, and over 340 British patents were granted between 1856 and 1973 on wave-powered generators. Schemes for wave-power conversion have been classified in accordance with their purpose, e.g., (1) propulsion schemes, (2) buoy power devices, (3) offshore power plants, and (4) shore-based power stations. They also have been classified in accordance with four phenomena upon which the operation of a wave-energy converter could depend. These are (a) variations in wave profile (slope, height); (b) subsurface pressure variations; (c) subsurface fluid particle motion; and (d) mass transport of fluid particles in breaking waves.

As might be expected, the most intensive research work in wave-power generation devices is being undertaken in the United Kingdom with some 150 people engaged full time in several government and university research laboratories. Their efforts are being coordinated by the U.K. Department of Energy Wave Energy Steering Committee. Two of the more advanced projects are S. H. Salter's "nodding ducks" (Figure 17), and Sir Christopher Cockerell's Hagen-Cockerell contouring rafts (Figure 18).

In 1976, a plastic and fiberglass 1/50 scale model of Salter's ducks was tested in a reservoir. The device consisted of 12 ducks on a 6-m (20-ft) spine. Its length later was doubled to improve power output. It reacted with waves as planned and is reported to have pumped water ashore. Power developed was reported to be 30 W, with 50 percent of available wave power absorbed.[9] A second series of tests commenced in Loch Ness in 1977. Waves there are about 1/10 the scale of those in the North Atlantic. This work by Lanchester Polytechnic is supported by a grant derived jointly from Sea Energy Associates, Ltd., and the Department of Energy. The Loch Ness device consists of a 160-ft (50-m)-long floating steel spine 3.2 ft (1 m) in diameter on which a string of 20 ducks is mounted. Each duck operates individually with its own hydraulic pump connnected to a common hydraulic power line. Power is fed to a power pack in the center of the spine, where it is converted to three-phase electrical power, then transferred to shore through a submarine cable. With design wind and wave conditions it will produce 15 kW. The best efficiency reported to date is 46.9 percent. The string has successfully ridden out Force 11 (64 to 72 mile per hour winds) conditions on the Loch.

The Hagen-Cockerell concept consists of a chain of floats on rafts, hinged together, which oscillate up and down successively with the changing slope of passing waves. Pumps on the hinges absorb the power generated by the relative motion of adjacent floats as a wave train passes and convert the energy into fluid pressure. Laboratory wave tank tests have yielded efficiencies similar to those obtained with Salter ducks.[9]. The floats respond to the smallest waves experienced, thus their length is less than one fourth a wavelenth of the designed sea state. This is 33 ft (10 m) for the North Atlantic.

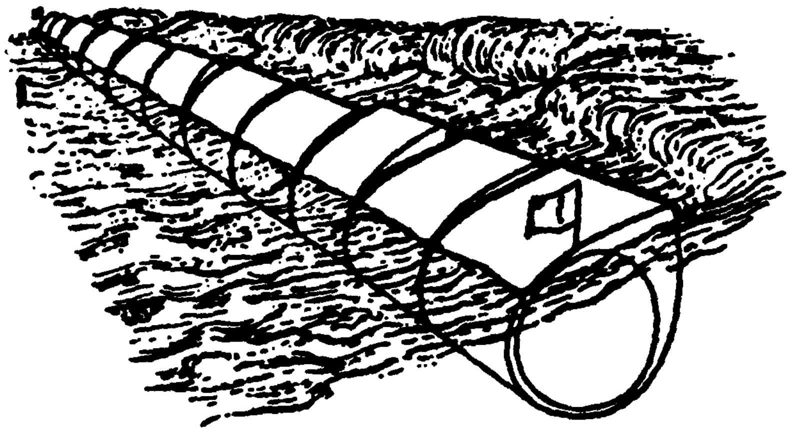


FIGURE 17 "Nodding Duck" Vane
Source: Salter. Wave Power. Nature, 1974.

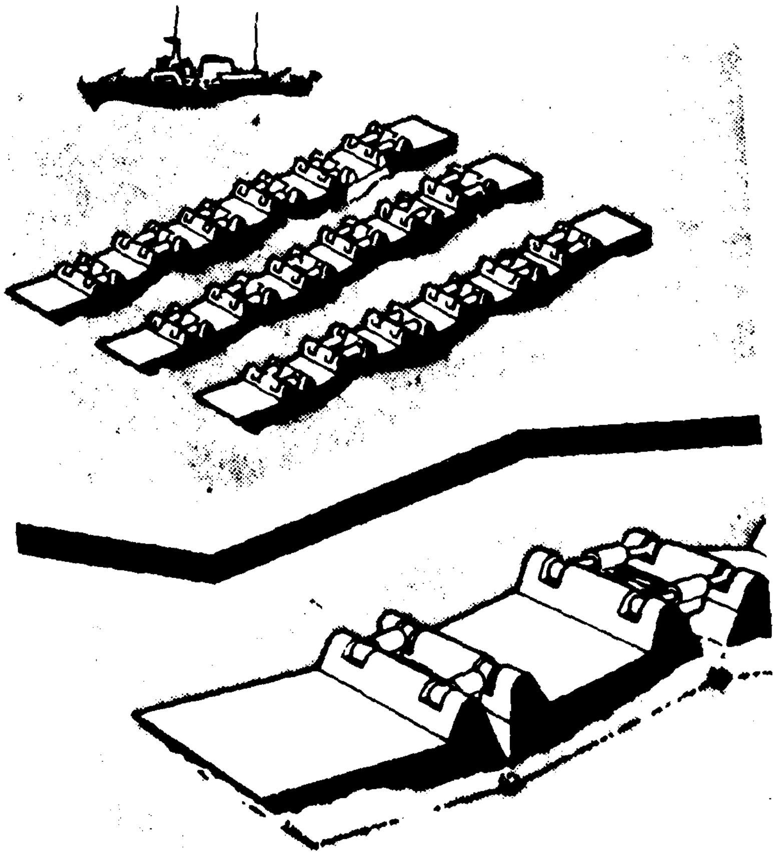


FIGURE 18 Contouring Rafts Wave-energy Conversion System
Source: Ocean Industry, August 1976.

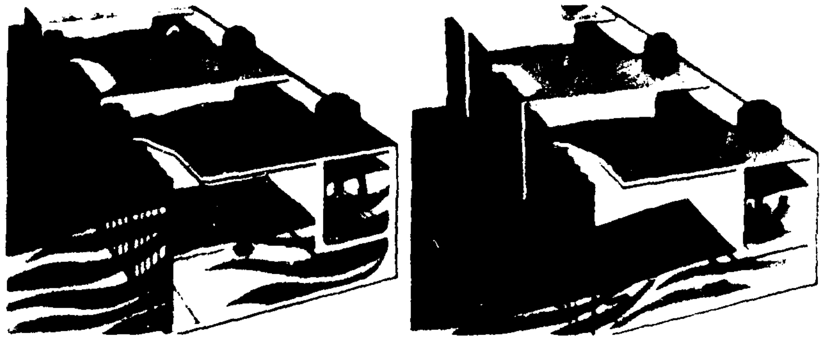
Trials of a 1/50 scale model have been completed; and trials of a 1/10 scale model are under way.

A number of new concepts have been proposed. These include submerged units that are operated by internal pressure fields and fluid particle motion, proposed by Vickers, Sussex University, and Bristol University; air turbines operated by oscillating water columns as proposed by Queen's University, Belfast, and Nottingham University; and a vane device that operates from the horizontal component of fluid particle motion in waves as developed by the Royal Military College of Science. Extensive trials will be necessary to demonstrate the effectiveness of these devices as compared with Salter ducks or Hagen-Cockerell rafts.

An interesting seabed-installed device has been termed a wave rectifier (Figure 19). A device of this type developed at the Wallingford base of the Hydraulic Research Station consists of two reservoirs, one above the other, and a vertical seaward face with an array of one-way flap valves arranged alternately to permit water to flow in or out.[9] The upper reservoir is filled with wave crests and the lower one is emptied in wave troughs. Flow between the reservoirs operates a hydraulic turbine connected to a generator. Although most of such a plant would rely on power technology, the hydrodynamic, mechanical, and structural design of the gates will require significant development effort. The estimated conversion capability of an optimized wave rectifier is a mean annual energy output of 5 kW/m (3.2 ft) of length.

The Japanese also have a significant wave-energy conversion development program under way.[9] Extensive sea trials have begun in the Sea of Japan of a 500-ton ship-shaped platform, the KAIMEI. It was designed by M.Y. Masuda of Japan. It uses air pressure developed by oscillating water colums to drive turbines (Figure 20). During initial trials, three Japanese turbines with a total capacity of 770 kW are being used. As of September 1979 eight Japanese-, one U.S.-, and one U.K.-designed turbines were planned to be installed for a total capacity of 1 to 2 MW. The platform already has ridden out one typhoon with wave heights to 13 ft (4.1 m). Normal operating sea state is 6.5-13 ft (2-4 m) with storm waves to 20 feet (6 m).

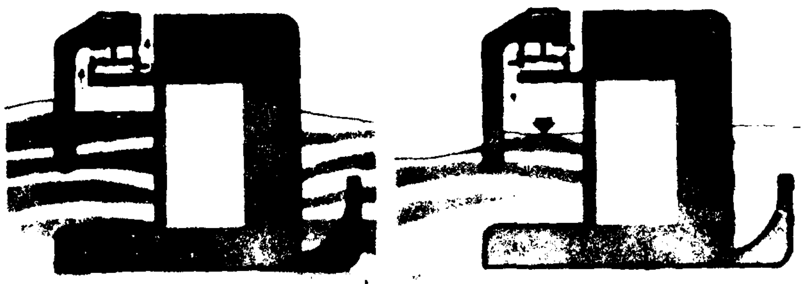
Current U.S. Department of Energy-sponsored wave-energy research is modest. Interest has been expressed in the Dam-Atoll developed by Lockheed. The device is a 250 ft- (75-m) diameter concrete dome that floats just below the surface of the sea.[10] Wave energy is focused into its center, where a swirling column of water energizes a turbine (Figure 21). Lockheed estimates indicate that each unit would generate 1-2 MW (presumably from waves having power levels of 40 MW/kW) at a cost of $3000/kW.



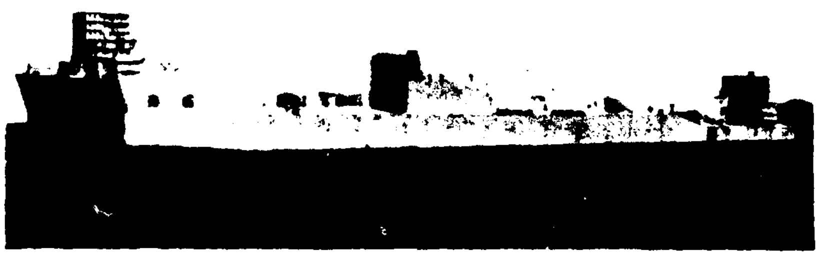
HOW IT WORKS. As an incoming wave hits the structure, the outlet gates close and the inlet gates open into an upper reservoir. Water is forced through the generating unit to the lower reservoir. As the wave retreats, the inlet gates close and the *outlet gates open*. Water trapped in the upper reservoir flows through the generating unit and out the gates.

FIGURE 19 Wave Rectifier

Source: Cranfield, J., 1979, "Interest in Wave Power Growing," Ocean Industry, 14, 2:67-68.



HOW IT WORKS. As the waves pass, air is forced in and out of the opening at the top and through a turbine.



SYSTEM IN OPERATION. The *Kaimei* is being tested in the Inland Sea of Japan and has weathered one typhoon.

FIGURE 20 Oscillating Water Column Converter

Source: Cranfield, J., 1979, "Interest in Wave Power Growing," Ocean Industry, 14, 2:67-68.

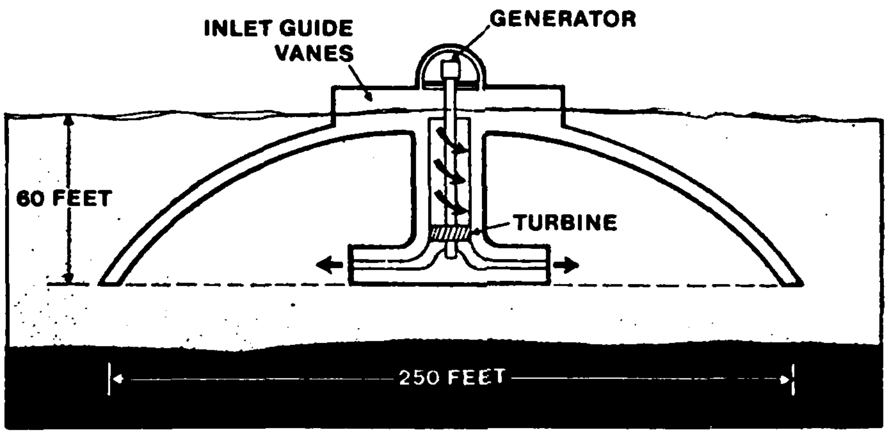


FIGURE 21 Dam-Atoll Wave Energy Unit

Source: Editor, "Artificial Island Taps Wave Power," Offshore Engineer, August 1979.

Constraints against Development

Legal constraints against the construction of wave-energy conversion plants are similar to those affecting OTEC plant development. They have the additional problem that any significant power-conversion level will require the emplacement of long chains of conversion plants. These will form barriers to free access from the shore to open sea as well as presenting fixed navigational hazards to all other users of the seas.

While policy in the United Kingdom has encouraged a significant research and development effort addressing wave-energy conversion systems, priorities and incentives in the United States have placed emphasis in other directions. This in part is caused by the short length of productive coastline relative to the total continental U.S. shore as compared with the U.K. shore.

Although technical problems in some areas can be solved with state-of-the-art approaches, structures that will endure the buffeting of seas in the most productive areas will be huge. In addition, it can be anticipated that mooring loads will be orders of magnitude more severe than any experienced by present-day offshore structures, or even of those anticipated for OTEC plants. To date only very small-scale models have been tested. Hence the step up to full-scale prototype plants will present formidable problems.

Investment uncertainty for wave energy conversion plants is as great, if not greater, than that for OTEC plants and stems from the same basic reasons, i.e., too little firm engineering, production, and operational experience on which to base credible cost projections. Further, available estimates indicate significantly higher costs per kilowatt than for ocean thermal energy plants. A recent MIT Sea Grant study, for instance, shows a range of $4305/kW to $12,967/kW depending on the site for Salter ducks.[11] Somewhat lower costs have been projected for Lockheed's Dam Atoll.

Incentive for Development

Incentives for development of wave-energy conversion systems are analogous to those for the development of ocean thermal energy. In view, however, of the much lower potential resource availability to the United States, it appears unlikely that significant federal resources will be made available or that specific actions related to wave-energy systems alone will be taken in the time frame appropriate to this study.

Maritime Industry Opportunities

Wave-energy conversion systems of the types that have been afforded the greatest development effort, e.g., Salter's ducks, Hagen-Cockrell

rafts, and Masuda's oscillating water columns, would require significant amounts of shipyard or marine industry support if they were to be built in meaningful numbers. However, the relatively early stage of their development, the relatively few suitable sites in the United States, and the concentration of development effort overseas, indicate that there will be little if any opportunity for the U.S. marine industry in their production within the 1980-1990 time frame.

Potential Benefits

As noted above, the potential benefit to the United States in the conversion of wave energy appears to be low.

Ocean Current

Ocean currents result from the interaction of a number of geophysical phenomena, including the rotation of the earth, the winds, the distribution of salinity and temperature, tidal effects, and the shapes of the ocean basins. The total power of ocean currents has been estimated to be about 5000 GW, but not all of this power is available, because energy extraction is practical only in a few areas where the currents are concentrated into ribbons of relatively high-velocity flow and high water volume transport. Consequently, an optimistic limit to the power that is accessible and could be extracted practically for useful purposes is 1 percent.

The extractable energy per unit of a vertical cross section is relatively small because ocean currents move at slow velocities in hydroelectric terms. Thus, while the total power of the Florida Current of the Gulf Stream is estimated to be in the order of 25 GW, only a small portion would be recoverable. However, even a small percentage would be beneficial to nearby electrical load centers.

Recovery Systems/Technology

Various concepts have been proposed for the conversion of current energy. Most have been derived from hydroelectric technology. These include Kaplan, propeller, and vertical-axis turbines. Other schemes include Savonius rotors[12] and a loop of parachutes pulling an endless cable.[13]

At present, DOE is supporting preliminary studies of a large ducted turbine by AeroVironment, Inc., of Pasadena, California. The turbine is of unique design in that the blades are supported around the periphery by liquid bearings. Generator elements would be built into the supporting duct. Studies currently are addressing possible environmental effects, hydroelastic stability of the rotor blades, and the mooring and anchoring systems. Preliminary results are reported to

be promising. It must be recognized, however, that all elements of the system are highly developmental.

Constraints against Development

Legal constraints against the construction of current energy-conversion plants also are comparable with those affecting ocean thermal-energy conversion plants.

Environmental effects of extracting significant amounts of energy from the Gulf Stream are a matter of concern. Thus, while AeroVironment has proposed extracting as much as 10 GW for the Florida power grid from the Florida Current, McCormick has hypothesized that removal of 10 percent of the energy of the Gulf Stream along the Southeastern Coast of the United States could significantly alter the climates of the countries of northern Europe.

Introduction of the large structures necessary for current energy conversion into such heavily traveled waters as the Straits of Florida could pose a hazard to navigation, thus significant restrictions would be imposed on the location and depth at which they would be installed.

Because of the early stage of design development of current energy-conversion units, cost estimates are highly speculative. Present estimates are on the order of $2500/kW, well above anticipated costs for commercial ocean thermal-energy-conversion systems.

Incentives for Development

Ultimately, similar policy and financial incentives that have been suggested for ocean thermal energy would promote the development of current energy-conversion systems. However, a much more intensive research and development program must be carried out successfully before it is likely that significant prototype and commercial plant-development programs would be initiated.

Maritime Industry Opportunities

Production of prototype and commercial ocean-current energy-conversion plants would require major support from the maritime industry to produce the plant/platforms and the mooring systems, to install the plants, and to service them. Given the current state of development of such plants, and the modest level of government support now for relevant research and development, it appears unlikely that such marine industry support will be required until well into the twenty-first century, if then.

Potential Benefits

The only area in which ocean current energy would appear to be beneficial to U.S. interests is off Florida. The maximum potential there seems to be no more than 1 to 2 GW without serious environmental consequences.

Tidal Energy

Tides ebb and flood primarily in response to the gravitational attraction of the Moon and, to a lesser degree, of the Sun. High tides occur at the upper and lower transits of the Moon, which produces semidiurnal (twice daily) tides as the Earth rotates. Superimposed on this pattern is a daily tide caused by the changing angle of incidence to the Sun and Moon's gravitational attraction, and spring and neap tides, which result from the relative positions of the Sun and Moon in regard to the Earth. In addition to the effects of the Sun and the Moon, basin geometry and geostrophic forces, such as the Coriolis force, affect tidal range and pattern.

The total tidal energy dissipated by the Earth is estimated at about 1400 GW, of which 1100 GW is accounted for by oceanic tidal friction in bays and estuaries that theoretically could be captured and converted to electric power. The only practical sites for recovery of tidal energy are in shallow seas, estuaries, and embayments, where a tidal range of 5.5 m (18 ft) is generally considered to be the minimum required to generate electricity. Thus, not every shallow coastal area has a tidal range suitable for power development. The amount of tidal energy that potentially could be recovered at suitable sites around the world is estimated at about 20 percent of the total, or about 200 GW. Of this energy, only an estimated 13 to 14 GW is recoverable by conventional hydroelectric practice. Since that world total represents only 3 percent of total U.S. electric power capability, tidal energy frequently is considered of little importance. However, while tidal energy cannot be a major contributor to the national energy mix, it can be of major local importance, especially when used in conjunction with other power sources in a regional grid.

Worldwide, there are about 100 favorable sites for the construction of tidal power stations. A number of these are in northern Europe. The largest existing tidal power plant is in Rance, near St. Malo, France, with a 240-MW capacity. The Soviet Union has a pilot plant located north of Murmansk with a capacity of 0.4 MW. In China, 40 small tidal power plants, with a total capacity of 0.6 MW were reported to have been built in 1958. Also, in 1958, 88 more tidal power plants were reported to be under construction with a total capacity of 7 MW. The largest of these plants is the Taliang facility, with a total capacity of 0.3 MW, operating on the Shunte River near the sea coast. In the Western Hemisphere, the known potential sites are on the Bay of Fundy or the Passamaquoddy Bay in the United States and

Canada, with potentials totaling 1.9 GW, and in Cook Inlet, Alaska, near Anchorage, with potentials totaling 6 MW.

Recovery Systems/Technology

The basic concept of capturing tidal energy is to enclose a basin with a barrier equipped with sluices and turbines and to allow the basin to fill through the sluices at high tide and empty through the turbines at low tide. Several different tidal power schemes have been proposed, especially to deal with retiming power output. Tidal cycles are not necessarily in phase with demand peaks. Thus a number of proposed tidal generation schemes seek to coordinate peak tidal power output with demand peaks. Some schemes are designed to produce power only during ebb tide or during flood tide, while others are designed to produce power during ebb and flow tides. Although there are many possible arrangements, the simpler schemes are generally preferred and tend to be the most economical.

Constraints against Development

A major constraint against the development of tidal energy conversion plants in the United States has been the remote location of the available resource relative to electrical load centers. Because of the inevitable association of the major topographical changes that such plants will require with highly sensitive coastal region environmental considerations, many environmental impact difficulties can be anticipated. Added to those constraints is the high capital cost and risk that has been noted in previous ocean energy systems. The International Joint Commission estimated in 1960 that a 300-MW installation at Passamaquoddy would cost \$1613/kW; at its estimated average annual output of 210 MW, the cost would be \$2305/kW.

Incentives for Development

Improvements in electric power-transmission-system technology since the early studies of Pasamaquoddy make its power economically available to more distant load centers. Or, its power could be used locally for a power-intensive industry, just as it has been proposed to locate OTEC plant ships in the tropic waters of the South Atlantic off Brazil. Again, governmental policy and financial incentives combined with the developing desperate energy situation could provide the needed incentive to undertake such a project.

Maritime Industry Opportunities

Development of tidal energy-conversion projects are viewed primarily as civil engineering projects. Therefore, with the exception

of possible dredging and associated support craft operations, little or no maritime industry involvement can be foreseen. Furthermore, as far as U.S. resources are concerned, there are at most two projects, Passamaquoddy and Cook Inlet. It is doubtful that even these will be undertaken in the time frame of this study.

Potential Benefits

The potential benefits of the tidal energy resource available to the United States appear to be minimal in comparison with the need.

Wind Energy

The amount of power that can be derived from the wind is proportional to the cube of its speed. Thus, the payoff in wind-energy conversion installations is predicated on locating them on sites with high wind speed. Some of the locations with the highest sustained winds are known to be offshore over the oceans and larger lakes. Consideration is being given to the deployment of wind-energy conversion systems offshore to utilize this potential source of energy, especially for the production of electric power. But, while the potential appears substantial, even onshore winds have yet to be tapped for significant energy production. Also, the technical, economic, and institutional problems involved have not been sufficiently analyzed to allow reasonable estimates of the future utility of the resource.

Theoretically, 59.4 percent of the energy in wind could be extracted by a perfectly designed turbine. Practical considerations, however, tend to reduce this value considerably. Therefore it appears that only about 20 percent (or less) of wind energy can be extracted and converted to commercial electricity. The total size of the offshore wind resources that may be tapped to supplement U.S. power requirements is great. It has been estimated that wind-energy conversion systems located at favorable sites along U.S. seacoasts and in the Great Lakes region could produce 170 GW of electricity. The most attractive wind power densities are along the Atlantic coast, from the Canadian border to the Virginia-Carolina region (in the path of the prevailing westerlies). Comparable wind-power densities are developed along the Aleutian Chain as a result of the Aleutian winter low-pressure area. The wind resources along the Pacific coast are not so large but are still potentially important. Other regions of the country having potential wind-power value are the eastern Great Lakes and the Texas Gulf Coast. The energy content of the offshore winds is considerably greater than that over adjacent lands during any season of the year, but offshore wind power can vary according to the season. Thus it is important that the seasonal variations in offshore wind power match the user demand for energy. Overall there seems to be a good correlation between offshore-wind-energy availability and energy demand. In the Northeast and the Pacific Northwest, maximum offshore

wind power and maximum electricity demand are both in winter. On the Gulf Coast, however, the spring offshore wind-power peak lags peak electricity demand by about three months. When such mismatches occur, schemes must be devised to provide for long-term energy storage.

Recovery Systems/Technology

Windmills represent one of the oldest technologies, with many developments over the years to improve efficiency and reliability. At one time the farmlands of the United States were dotted with small machines to pump water and to provide electric power to single-dwelling units and appurtenant farm buildings. Current developments are aimed at further improvements in efficiency through the use of advanced aeronautical technology and major increases in the power output of individual units. Machines with potential maximum outputs up to 2.5 MW are under development.

Constraints against Development

Because the large aggregations of units proposed for sea-based installations would be moored offshore, all the constraints cited for other ocean-energy schemes would apply equally to wind energy. In addition, it must be recognized that the energy source is not unique to the ocean environment but is equally available inland as well as along the coast, although perhaps not with the same intensity. The only difference is the cost of the "acreage" on which the conversion plants would be installed. At some $70,000 to $120,000 plus cost per acre for prime shorefront, the estimated over $12 million cost per acre of floating platforms of reasonable shiplike proportions does not appear attractive.

Incentives for Development

There do not appear to be any reasonable incentives for the development of seagoing wind-energy conversion plants in the forseeable future.

Maritime Industry Opportunities

There appear to be no maritime-industry opportunities in the time frame of this study.

Potential Benefits

Aside from possible stronger concentrations of wind energy at sea, there appear to be no substantial benefits until all potential land-based wind resources have been thoroughly exploited.

Salinity Energy

In principle, it is possible to derive energy from any process in which two or more liquids of different chemical composition are mixed. Energy-producing devices have been made that depend on mixing two systems of water of different salt (sodium chloride) concentration. Salinity gradient energy converters employ osmosis for their operation, a basic physical process fundamental to life. In this osmosis, a membrane selectively permits the passage of a liquid but not the salts contained in solution in the liquid. Salinity gradient-energy converters make use of the osmotic pressure differences between solutions of different concentrations of salt. In most of these devices, the osmotic pressure difference is converted into a usable form of energy such as mechanical energy, which is in turn used to produce electricity. When specially designed cells or batteries are employed, electricity can be generated directly.

The large-scale technology to extract energy from natural salinity gradients is in its infancy, and an array of economic, technical, and environmental problems remains to be solved. Considerably more research and development is needed, especially in the areas of reduction of membrane costs and increases in reliability, before the potential of this resource can be realized. Tentative plans call for construction of demonstration units during the next 10 to 15 years, but it is not yet possible to forecast when (or if) full-scale commercial plants will be in operation. The environmental acceptability and economic feasibility of such plants must be demonstrated first.

Salinity gradient power plants can, in principle, be constructed at any man-made or natural site where water systems with different salinities mix. Indeed, small scale plants are now in operation (e.g., Israel) using this system. The marine termini of freshwater systems (such as estuaries) would be potential sites, but plants built adjacent to hypersaline sinks, bodies of very high salt concentration such as the Great Salt Lake or the Dead Sea, would be more attractive.

Salinity gradient power is the most concentrated form of renewable power available from the oceans and has the highest energy density, with an estimated 3540 GW theoretically available from several potential major sources worldwide. It has been suggested that at least as much energy can be extracted from river and stream flow using salinity gradient converters as is extracted using hydroelectric facilities. In the United States, 14 percent of its electrical power (about 62 GW) is derived from hydroelectrical plants, and it is not expected that salinity power will exceed this figure, if, indeed, it is commercialized at all.

Currently, DOE is sponsoring several basic research projects in salinity energy conversion. These include an osmotic pressure power unit and a dialytic battery. The primary problems associated with salinity gradient technologies lie in three areas: membrane

technology, pretreatment of feed brines, and waste brine disposal. Most emphasis was directed toward membrane technology initially, but it now has shifted to the latter two areas. Since membranes are subject to attack by biological organisms, feed stocks must be pretreated before entering the power systems. In addition, environmental concerns will affect the manner of disposal of waste brines.

Maritime Industry Opportunities

Given the very early stage of research and development for this technology, and the fact that inland sites are much more likely to be economically useful, there is no foreseeable maritime industry opportunity within the time frame of this study.

Bio-Conversion Energy (Biomass)

One method by which ocean solar energy may be utilized is ocean farming. The conversion of marine plants to useful forms of energy, such as methane gas, is technically feasible. The problems that arise in considerations of commercial biomass energy conversion are primarily those of scale. The use of marine plants as a source of methane or liquid hydrocarbons is not new; marine organisms are believed to be the original source material for most of the petroleum and natural gas deposits. In ocean farming and biomass energy conversion, the ocean plant material is directly converted into hydrocarbons, eliminating the need for millions of years of geological time to complete the transformation.

Several species of marine plants are potential candidates for ocean cultivation. In general, plants with high growth rate or primary productivity (such as kelp) are preferred. Kelp beds are particularly abundant in the temperate zones and are found in sufficient quantity for commercial harvesting in many areas of the world. A true ocean farming concept, however, involves more than harvesting naturally growing kelp. By supplying nutrients from cooler deep waters and attaching the plants to a supporting structure, kelp can be raised anywhere in the ocean. Conservative projections show that ocean farms would be able to capture and store about 2 percent of the incident solar radiation, or about 117,000 kW-hours per acre per year. About 4 percent of this crop energy can be converted into human foods and the rest processed into other forms of energy such as substitute natural gas (SNG). An economic bioconversion process would have an efficiency of about 40 percent, resulting in a food energy yield per acre per year sufficient to meet the requirements of four to five people. In addition, the recoverable SNG output per acre would be about 160,000 cubic feet per year.

In terms of domestic needs, a square of ocean surface 750 km (470 miles) on a side could supply the energy requirements of the present U.S. population.[1] However, as an example of the limitations of scale, if an ocean farm of this size had to rely completely on pumped deepwater for its nutrient supply (no nutrients supplied by natural upwelling), it would require nearly one trillion gallons per minute, which is the cooling water requirement of some 2-million 1000-MW power plants. Its output potential would be about 770 GW and would represent a probable upper limit to energy from potential ocean farms.

The technology involved in oceanic biomass plantations is relatively basic. One design concept consists of a platform mounted on a large central spar buoy that would contain processing plants, holding tanks, living quarters, navigational equipment, buoyancy controls, and a helicopter platform (Figure 22). Transfer facilities would include equipment for taking kelp aboard from harvesting ships and for loading gas and feed aboard product ships. Suspended below the spar buoy, about 980 feet (300 m) of pipe would permit cold water to be pumped from depth by means of a wave-actuated pump to resupply nutrients to the kelp farm. The kelp would be attached to concentric lines or a mesh system suspended 40-80 feet (12-25 m) below the surface and strung between radiating hollow structural support members, which would also serve as the nutrient distribution system. A position-keeping propeller would be mounted on the buoy. The farm unit in this concept would be about 1000 acres (400 ha), and its major fuel product would be SNG, accomplished probably by digestion, a biological process similar to that used in many sewage treatment plants.

The environmental concerns with a single or a few scattered ocean farming operations would probably be minimal. However, if a large area of ocean surface were devoted to an array of ocean farming units with cooler deepwater being pumped to the surface, thermal anomalies of sufficient size might develop to have a possible impact (either beneficial or detrimental) on the weather. Ecological impacts arising from upwelling nutrient-rich cooler waters would likely be more beneficial than detrimental. Use conflicts could arise if very large areas of the ocean surface were to be utilized for farming. Ships navigating in farming areas could not only damage the plantation but might receive damage themselves. Currently, there are no oceanic biomass energy plantations in operation. In some areas, however, naturally occurring kelp is being harvested for algin, a gum material, which is used as a stabilizer and an additive to foods and to industrial compounds.

No cost estimates are available for "farms" such as the one illustrated, but given the estimated production capability of 10,000 kWh per acre per year or roughly 1 MW for the planned 1000-acre (400-ha) installation, and the implied size of the installation, capital costs would appear to be significantly greater than those for an OTEC plant.[14]

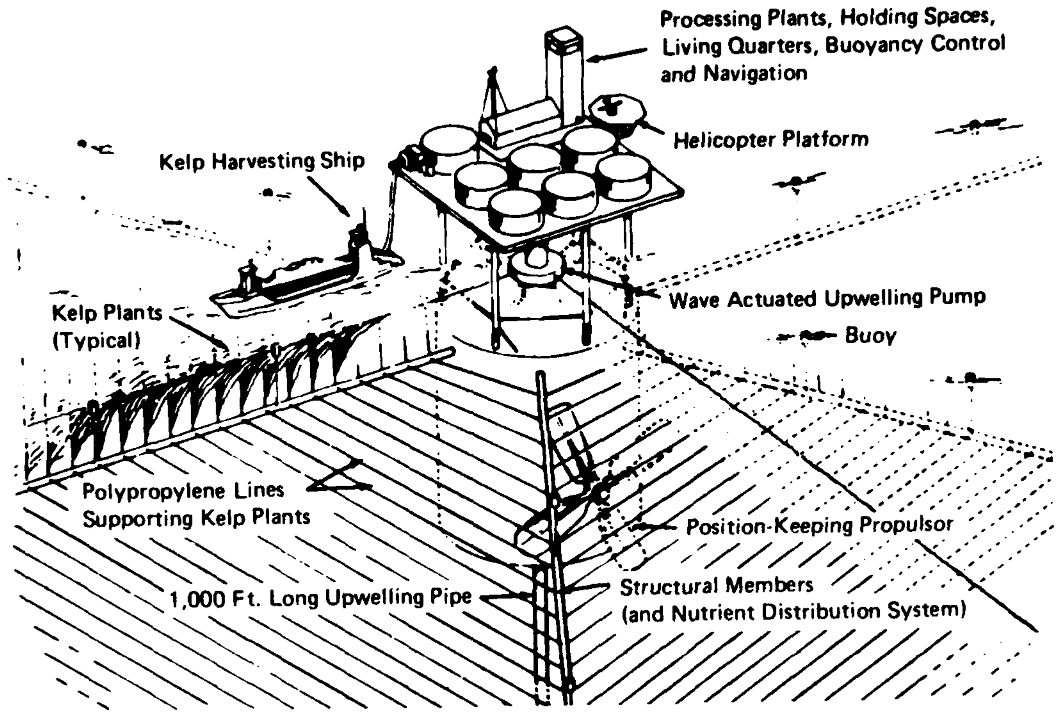


FIGURE 22 Conceptual Design, 1000-acre Ocean Food and Energy Farm Unit

Source: Wilcox, Howard, Ocean Farming. In Proceedings of a Conference on Capturing the Sun Through Bioconversion. Washington, D.C. 1976, p. 258.

Maritime Industry Opportunities

There appears to be little or no probability of sufficient development of maritime bioconversion energy systems in the time frame of this study to provide any significant marine industry opportunity.

Geothermal Energy

Geothermal energy is the natural heat of the earth, which increases with depth. The heat is stored in the rocks and water within the earth and can be commercially extracted by drilling when it is anomalously concentrated at rather shallow depths. Water or steam transfers the heat from the hot rocks and waters at depth to the well bore and up to the surface. Present utilization of geothermal energy in the United States amounts to about 520 MW of electrical power from The Geysers dry steam field in northern California plus an estimated total nonelectrical utilization of between 15 and 16 MW in Oregon and Idaho. Total world geothermal electrical generating capacity is just under 1300 MW, with over 560 MW in the construction stage. There has been an acceleration of the slow, but steady, increase in world geothermal activity since the oil price rises began in 1973. The increased activity has not had a major effect as yet on the world's installed geothermal capacity because of a lag of as much as five years between the discovery of a field and its actual commercialization. Also, the electrical capacity figures do not reflect the growth of the direct use of geothermal energy for space heating.

The potential for the existence of geothermal deposits beneath the seafloor is great. Geothermal fields would be expected to be located in areas of young tectonism and volcanism such as those that occur along the boundaries of the mobile plates that make up the Earth's crust. Boundaries of crustal plates that are moving away from each other (spreading ridges) make up only about 1 percent of the Earth's surface but account for about 20 percent of its heat loss. It has been estimated that a major geothermal convection system may exist every 32 miles (20 km) on the mid-Atlantic Ridge (upon which Iceland, with its large geothermal resource, is situated) and every 1.8 miles (3 km) on the fast-spreading East Pacific rise. Also, a new source has been identified in the Gulf of Baja California. Crustal plate boundaries are geologically unstable, possess a high earthquake incidence, and are mostly submarine. One such area occurs in the Red Sea deeps, which contain geothermal brines in deeps originating from hydrothermal discharge from the seafloor. Some of these brines have estimated surface temperatures of over 392°F (200°C).

A preliminary study by Britain's Department of Energy suggests that the heat recovered from hot rocks or hot fluids of hydrothermal systems beneath the floor of the North Sea might cost less than that derived from imported oil. The report estimates that the heat beneath each square kilometer of seafloor could be recovered at a rate equivalent to

from 1,000,000 to 1,500,000 barrels of oil per year for 20 years. The North Sea basin contains some of the highest temperature gradients recorded in the United Kingdom. The study concludes that it would be impracticable to attempt to exploit heat from the North Sea floor if the platforms had not been built to develop offshore oil and gas. The possible future utilization of the geothermal resources of the North Sea would continue energy production from the region beyond the life of the oil and gas fields and, thus, could be of great importance to the nation.

In deep sedimentary basins of relatively young geological age, the sediments are usually undercompacted below depths of 2-3 km (0.6-1.8 miles). Therefore, the fluid contained in the rock formations carries a part of the overburden load, thus being subjected to intense pressure. Heat continually rising from the earth's interior is absorbed by these fluids, and their tempertaure becomes much higher than is normal for their depth of occurrence. Other important characteristics of these hot geopressured fluids are low salinity and a methane saturation of up to 1 cu m (35 cu feet) of gas per barrel of water. Thus, energy is potentially available from geopressured deposits in the form of heat, pressure, and methane gas. In the United States, the major example of this geological condition is found in the Gulf of Mexico basin along the Gulf Coast. Geopressured zones in the Gulf of Mexico basin are known to occur in geologically young sediments beneath an area of over 111,400 square miles (278,500 square km) along the Texas-Louisiana coast and extending offshore to the edge of the continental shelf. In a recent assessment, the U.S. Geological Survey estimated that the geopressured fluids of the Gulf Coast could contain (in the assessed onshore geopressured zones) as much as 3000 GW-years (or more) deliverable at the wellhead, especially if the energy equivalent or recoverable methane is considered. The Geological Survey did not estimate offshore geopressured potential because of a lack of data but indicated that its potential may be even greater than that of the assessed onshore portions of the Gulf.

Electrical generating plants normally create heat as a by-product of their operation, and this also is the case with geothermal plants. Thus, thermal pollution becomes a problem when dealing with great volumes of heated water, if the water is not reinjected back into the geothermal reservoir in a closed-loop system. Although efforts are under way to employ this heat for mariculture, the adverse impact of hot discharge water is often felt at some distance from the plant. Other possible environmental impacts include subsidence, increased tectonic activity (earthquakes), noise pollution, water pollution, and air pollution. However, careful research and planning along with good well and reservoir engineering should provide the practice and the technology to utilize offshore geothermal and geopressured deposits for the production of energy in an environmentally acceptable manner.

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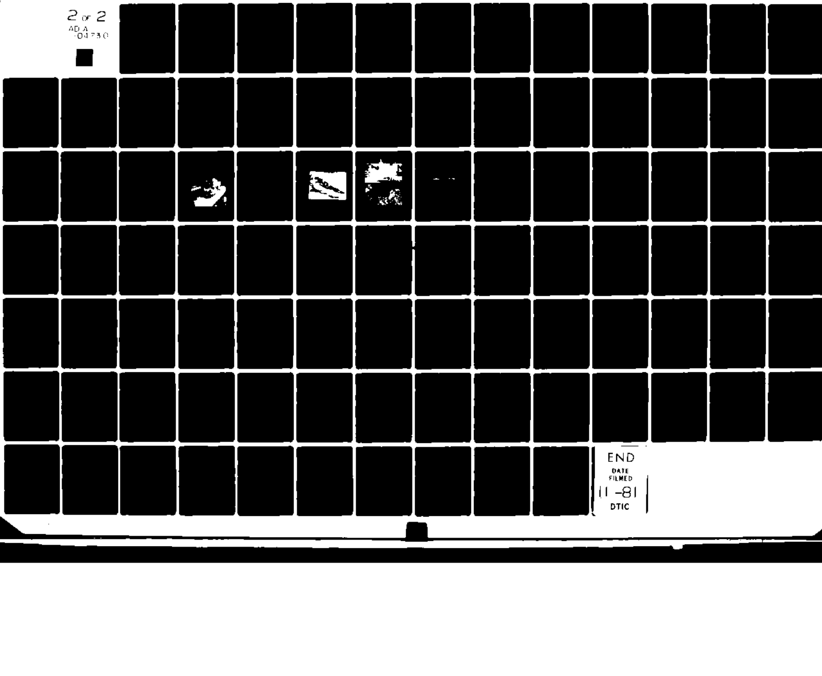

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Maritime Industry Opportunities

As with wind energy, geothermal energy is not unique to the oceans. Therefore, there is little likelihood that the ocean resource will be developed before its land-based counterpart has been thoroughly exploited. Consequently, no maritime industry opportunity is seen from this ocean resource within the time frame of this study.

Hard Minerals

Coal and other minerals have been mined beneath the seafloor for many centuries. Today, there are over 100 underground mines operating under the ocean bottom. Coal resources under the seabed are not well known or quantified but in some areas are presumed to be immense. Subsea areas with good prospects for large deposits of bituminous coal include the continental shelf off Siberia and off northern and western Alaska. Apparent worldwide undersea coal resources are estimated to be roughly three-eighths of the land resources, with offshore anthracite coal resources estimated at the equivalent of 43,000 GW-years (43,800,000,000 tons) and offshore bituminous coal resources estimated at the equivalent of 450,000 GW-years (464,500,000,000 tons). Thus, total world offshore coal resources are estimated to be equivalent to 499,000 GW-years (508,300,000,000 tons). The conversion to megawatts assumes that the entire offshore coal resource would be converted to electrical energy at a constant rate for a one-year period. These estimates, however, are little more than sophisticated speculation, as there has been very little exploration and drilling for offshore coal resources. In 1967, there were 57 undersea coal mines in operation throughout the world, with a total annual production of 33,500,000 tons (about equivalent to 33 GW-years). These mines were located in Japan, England, Scotland, Nova Scotia, Taiwan, Turkey, and Chile. About 30 percent of Japan's total coal production comes from undersea mines.

Although not being utilized at present, there are other offshore mineral energy resources. Extensive deposits of oil shales are believed to occur off the coasts of Brazil, southern California, and South Africa and in the Mediterranean and Red Seas. Tar sands are known in continental shelves off southern California, Trinidad and Tobago, and Venezuela. Some speculations indicate a possible world resource of one-trillion barrels (about equivalent to 194,000 GW-years) of oil in offshore oil shales and other bituminous rocks on the continental shelves to a depth of 1000 feet (305 m). A total of 200-billion barrels of oil is speculated to be contained in offshore tar sands to the same depth. This total is equivalent to about 38,800 GW-years. It is, however, unlikely that there will be commercial interest in any of these deposits until the technology and economics of exploiting them on land has been demonstrated.

Organically rich marine and inland lake sediments have been mentioned as a possible source of large amounts of methane gas, but

these suggestions are highly speculative, and much research will be required before such an energy option can seriously be considered.

Offshore uranium resources have been tentatively estimated to be equivalent to about 77,200 GW-years (29,400,000,000 grams of ^{235}U). In addition to offshore uranium resources in consolidated and unconsolidated deposits, uranium is also contained in phosphorite deposits. Phosphate deposits being mined onshore contain small amounts of uranium, which is recovered as a by-product of fertilizer production. Similar extensive phosphorite deposits occur offshore in many parts of the world. While there has been no direct interest in uranium recovery from offshore phosphorite deposits, there is serious interest in these offshore deposits as a source of phosphate. Presumably if offshore phosphorite deposits were developed, they too could become a secondary uranium source.

Hazards of subsea mining include the usual problems of onshore mining such as cave-ins, fires, and explosions, plus the possibility of disasterous flooding. While cases of subsea mine floodings have occurred, sufficient overlying rock cover has generally provided an entirely adequate seal, and operations have proven no more troublesome than similar operations onshore. Other environmental disturbances from subsea mining could arise from exploratory drilling or from the construction of artificial islands. Dredging will cause severe local effects and may reintroduce substances into the marine environment that could adversely affect the benthic organisms of adjacent waters. Each offshore mining operation will have different environmental parameters that must be considered to determine impacts and trade-offs in ocean use. Thus, it will be necessary to gather data in each area where ocean mining might occur.

The development of offshore hard-mineral energy resources is dependent on the costs of alternative sources of energy. In areas where subsea mines now exist, these have mainly been extensions seaward of older onshore mine workings. A main factor influencing the economic attractiveness of subsea mining is the potential to create a local energy supply with minimum transportation costs.

Maritime Industry Opportunities

The extension of present hard-mineral recovery operations from under the oceans will most likely take place using land-based mining operation extending from shore. The development of oil shale and tar sand resources could use dredging systems built by the maritime industry. However, it appears unlikely that these ocean-based resources will be developed until well after their land-based counterparts have begun to be exploited. Therefore, in either case there appears to be little or no maritime industry opportunity in the time frame of this study.

Conclusions

Of the renewable energy resources of the oceans--thermal differences, waves, currents, tides, winds, salinity differences, and biomass--only ocean thermal differences appear likely to offer an opportunity to the maritime industry within the time frame of this study. Further, none of the nonrenewable energy resources considered in this chapter--geothermal, coal, oil shale, and tar sands--will offer maritime industry opportunities in the study time frame.

The relatively early stage of development of ocean-wave- energy conversion devices and the relatively limited wave-length potential available to the United States indicate little if any opportunity for the U.S. marine industry in their production within the time frame addressed.

Given the present state of development of ocean-current energy conversion plants, and the very modest level of government support for relevant research and development, it appears unlikely that marine industry support will be required until well into the twenty-first century.

The development of tidal-energy conversion systems is viewed primarily as a civil engineering project. And it is doubtful that development of the two most feasible U.S. sites, Passamaquoddy and Cook Inlet, will be undertaken in the next decade.

It is unlikely that wind-energy-conversion devices will be put to sea before they have been thoroughly developed and exploited on land sites.

Given the early stages of research and development for the technologies of salinity difference energy conversion and marine biomass production, there is no forseeable marine industry opportunity--except for the support of research projects--in the time frame of this study.

As with wind energy, it appears unlikely that the development of ocean-based geothermal energy, coal (except as currently in mines extended from shore), oil shale, or tar sands will be undertaken until counterpart land-based resources have been thoroughly exploited.

Thus, of all the ocean energy resources, only ocean thermal differences appear to offer opportunities to the maritime industry in the next decade. Given the current pace of research and development, the major oportunity will be in the design, construction, installation, and operation of two or three 10- to 40-MWe demonstration OTEC plants. It is estimated that each such plant will require a peak marine industry effort of approximately 270 men per day. Should these plants prove the technical and economic feasibility of ocean-thermal-energy conversion, it is likely that a major commercial plant development and

production program would be initiated toward the end of the decade. Such a program could reach its full pace in the 1990's and extend into the early twenty-first century, with marine industry support requirements on the order of 8500 to 11,000 men per day.

Recommendations

In view of the conclusions above it is recommended that:

Government and industry effort concentrate on the removal of institutional constraints against the production of commercial OTEC plants.

Government and industry lend every effort to the early possible deployment of one or more demonstration OTEC plants.

Industry prepare for the production of platforms of reinforced concrete as well as of steel and for the possibility of unusual platform configurations, such as spars.

Industry also should keep abreast of developments in the other areas of renewable ocean-energy recovery in order to take advantage of any significant advances not perceived in the course of this study.

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CHAPTER 4
LIVING RESOURCES

Introduction

The demand for fishery products in the United States has shown a steady growth in the recent past. While the U.S. population has increased at an annual 1 percent rate since 1960, per capita consumption of fish has increased at a rate of 3 percent per year. Increasingly, U.S. consumers have demanded more fish for their daily diet. The 1978 per capita consumption of fish was 13.5 pounds compared with 12.8 pounds in 1977, an increase of 5 percent in one year.

To meet the enormous demand for fish, the United States has imported more than half of all its supply. Yet, the ocean and coastal resources of the United States are the richest in the world.

The current estimate is that as much as 20 percent of the known commercially exploitable marine fisheries of the world exist within the U.S. fishery zone, which extends 200 miles from shore. (The total commercial catch in 1977, worldwide, was about 63 million metric tons.) Despite the enormous potential, the U.S. fisheries industry has failed to exploit these resources fully. This, however, is changing, and within the foreseeable future, the U.S. fisheries industry can be the strongest in history.

This chapter focuses on the potential of the U.S. fisheries industry and discusses the present and future market demand and resources available. Constraints on the fisheries industry, as well as the immediate future of the fisheries industries, will be addressed. Naturally, where there is a future for the fishing industry, there is a future for the maritime industry.

Market Demand

Over the past 20 years, the U.S. demand for fisheries products has shown a healthy and steady growth. The U.S. per capita consumption of fish has increased in recent years, at the rate of 3 percent per year (5 percent in 1978 alone as noted above), contrasted with about a 1

percent population growth. As a percentage of the national food budget, U.S. expenditures on fish have increased to 4.9 percent in 1974, contrasted with about 2.5 percent in 1960. Expenditure at the retail level increased from $1.7 billion in 1960 to $7.4 billion in 1974. U.S. per capita consumption of fish from 1960 to 1978 is illustrated in Figure 23.

Resources

Many of the most valuable living and nonliving ocean resources are found within 200 miles of the United States coastline, which includes approximately 101,000 linear miles. Within the 200 mile perimeter are approximately 2,045,000 square nautical miles of ocean space. This ocean area is approximately three times larger than all the publically owned land in the United States and is roughly equivalent to about 30 percent of the total U.S. land mass.

Located within this 200-mile ocean zone are some of the most productive commercial fishing areas in the world. The current estimate is that as much as 20 percent of the known commercially exploitable fisheries resources of the world exists within 200 miles of our shores. The Food and Agriculture Organization (FAO) of the United Nations recently estimated the world's sustainable commercial harvest of fisheries resources at 100 million metric tons annually; approximately 20 million metric tons of the world resource was located in the U.S. coastal zone.

The 200-mile fishery zone contains the most abundant fisheries resource in the ocean. Yet, the United States imports nearly half of its fish supply. In 1978, the U.S. fisheries industry landed 6.0 billion pounds of fish, worth $1.8 billion. Additionally, approximately 5.5 billion pounds was imported, nearly half of the U.S. landings, worth $2.1 billion. Table 7 illustrates U.S. supply and value of fishery products for 1977 and 1978.

Despite the enormous potential of its fisheries resources, the United States has failed to develop a commercial fishing industry capable of fully exploiting these resources. In fact, the commercial quantity of catch by the U.S. industry increased only 6 percent from 1950 to 1977, from 2.233 million metric tons caught to 2.358 million metric tons. In sharp contrast, the world commercial catch, according to the FAO has increased 64 percent just during the past 15 years. In 1977, the U.S. fleet harvested only 4 percent of the world harvest despite the 20 million metric tons of sustainable fish catch available within 200 miles of our shores.

The U.S. fishing industry has failed to tap fully the enormous resource within the 200 mile zone, but consumer demand has steadily increased. This steady increase has been magnified by a constant population growth. Because commercial landings have not kept up with

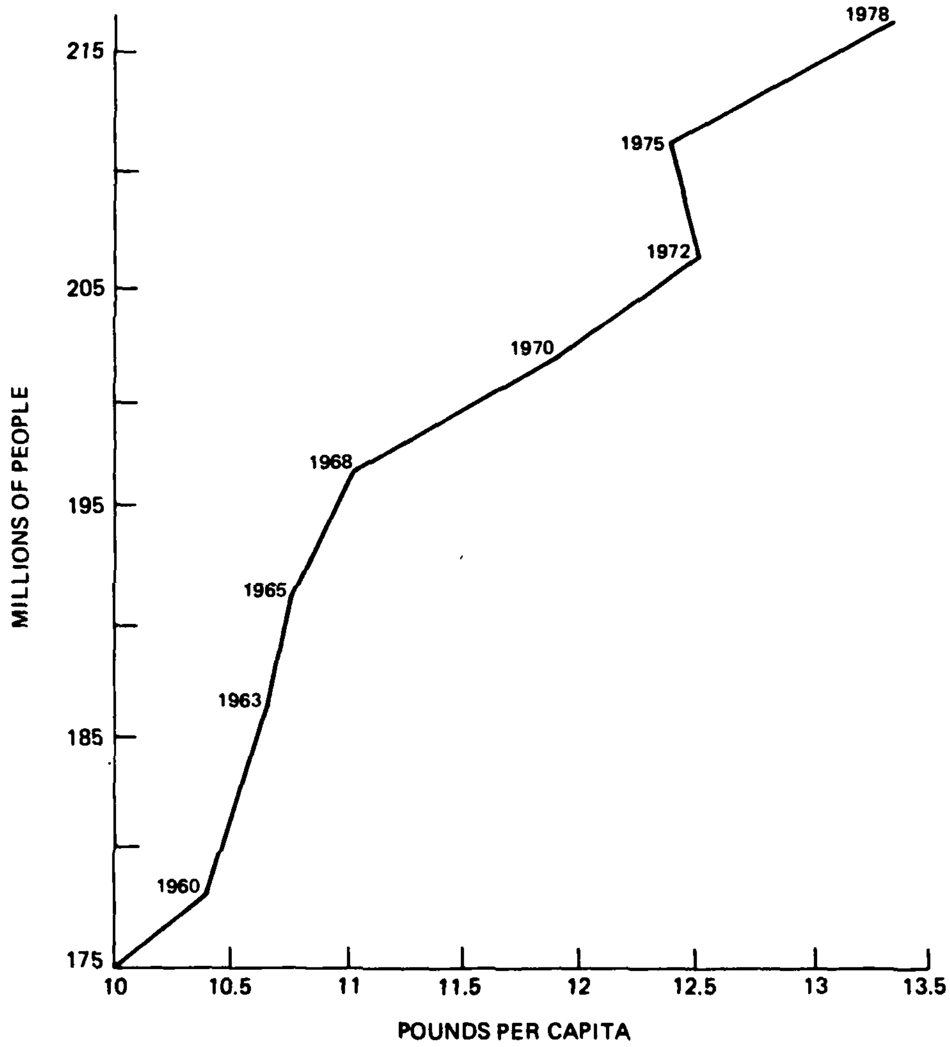

FIGURE 23 U.S. Per Capita Consumption of Fish

Source: Fisheries of the United States, 1978.

TABLE 7 U.S. Supply of Commercial Fish Products, 1977 and 1978

	Domestic 1977	Domestic 1978	Imports 1977	Imports 1978	Total Landings 1977	Total Landings 1978
			In millions of lbs			
Edible	2,900	3,177	4,514	4,958	7,414	8,135
Industrial	2,298	2,851	867	523	3,165	3,374
Total	5,198	6,028	5,381	5,481	10,579	11,509
			In million dollars			
Edible	$1,404	$1,733	$1,932	$2,108	$3,336	$3,841
Industrial	111	121	35	18	146	139
Total	$1,515	$1,854	$1,967	$2,126	$3,482	$3,908

Source: Fisheries of the U.S., 1978. National Oceanographic and Atmospheric Administration.

demand, the United States has imported much of its fisheries products. The impact of the failure to develop a U.S. commercial fishing industry capable of exploiting these resources has been considerable. For instance, in the 10-year period from 1968 to 1977 the U.S. has experienced a balance-of-trade deficit each year in fisheries products which has grown from $0.7 billion in 1968 to $2.1 billion in 1977. Since 1971, the balance-of-trade deficit in fisheries products has exceeded $1 billion each year, and, cumulatively, for the 10-year period, the total deficit has amounted to $12.6 billion. U.S. fleets now supply only one third of the edible fishery products consumed in the United States, while two thirds is imported from other nations. On a dollar basis, the U.S. imports $6 in fishery products for each $1 exported.

While the domestic fishing industry has failed to capitalize fully on U.S. resources, foreign fishermen have been active in exploiting these fisheries. Ironically, the same countries that have caught their fish from U.S. fisheries resources have exported their fish to the United States; as reflected in Table 7, imports generally are more expensive than commercial landings.

Constraints on the U.S. Fishing Industry

There are an estimated 88,317 fishing vessels and boats in the U.S. fisheries industry. Only 15,602, or 17 percent, exceed 5 gross tons.

Yet, this mere 17 percent has caught 75 percent of the total catch of recent years. In the past eight years, with the exception of 1973, over half of the vessels entering the fisheries industry have been from 5 to 29 gross tons. Only 7.8 percent of the vessels in 1974 were from 100 to 499 gross tons, and only 0.7 percent were over 500 gross tons. Clearly, there has been a dearth of efficient fishing vessels, and this lack has been a significant contributing facto: in the industry's inability to exploit available resources fully.

The U.S. fishing industry has long been characterized by fragmented and often family-owned small companies. A lack of big financial commitments explains the overabundance of small vessels in the industry. From the record, it is apparent that the federal direction provided in the past by the Department of the Interior and in recent years by the Department of Commerce has failed to address the need for better vessels. A recent presidential policy, however, promises to facilitate access to private venture capital for vessel construction. This policy is addressed in more detail near the end of this chapter.

With more efficient vessels, the U.S. commercial catch would undoubtedly increase. Because many of the U.S. potentially exploitable fisheries are within the 200-mile zone, however, vessels need be no larger than 49 to 94 feet, the average vessel size under construction today. Vessel construction has more than doubled from five years ago, when the shipbuilding industry built 528 vessels in one year. In 1979 there were approximately 1200 vessels under construction; the average vessel is 48 to 94 feet, or 100 to 200 tons.

Construction alone, however, does not represent the number of vessels entering the fishing industry; conversions, from another type of vessel to a fishing vessel, also account for vessels entering the industry.

Since the passage of the Fisheries Conservation and Management Act (FCMA), which extended U.S. jurisdictional limits 200 miles from shore, there has been a significant increase in the number of vessels entering the fisheries industry. Because of the potential in the fishing industry, there is reason to believe that the number of vessels entering the industry will continue to increase. Thus, lack of efficient vessels should be no constraint on the industry in the foreseeable future. However, the problem of finding increased numbers of fishing crew members willing to stay at sea for long periods in the large vessels will become more important as a constraint. Other factors constraining the U.S. fishing industry, include (1) the depletion of various species and (2) the effects of pollution, habitat degradation, and environmental pressures on commercial fishing activities.

For several hundred years one of the basic principles of freedom of the seas has been the freedom to fish wherever fish could be found, outside of the relatively narrow limits of jurisdiction traditionally

claimed by coastal states. As fishery technology became more sophisticated, fishermen and nations learned that the fishery resources of the sea were not inexhaustible and that freedom of fishing, as an international policy, resulted in damage to various commercially harvested fish stocks. For example, all but a few species of salmon have been depleted. In addition, the American lobster has been seriously overfished and oyster landings have steadily declined.

One of the major causes of the depletion of these stocks was the presence of large, and often government-subsidized, foreign fleets fishing off U.S. shores, from countries such as Japan, the Soviet Union, Poland, Canada, and the Republic of Korea. In 1971, the foreign fleets took 3.5 million metric tons of fish from the U.S. zone. With the promulgation of the Fisheries Conservation Management Act (FCMA) in 1976, foreign fishing in U.S. waters has decreased noticeably.

A contributing factor in the depletion of various species has been the U.S. consumer's demand for certain species. The U.S. population consumes 41 percent of world tuna landings and 27 percent of world shrimp and salmon landings. In addition, the U.S. population consumes a disproportionate share of other species, including 91 percent of world lobster landings. While U.S. fleets have been active in harvesting these species, millions of metric tons of sustainable harvest of other edible species, not commercially desirable because of consumer preference, have been largely overlooked by the U.S. industry. An example of the potential involved in underutilized species is shown in Table 8, which lists the 1973 U.S. catch and the estimated potential annual yield by species.

Undoubtedly, the development of an underutilized species market will bring rewards to the fishing industry. The estimated annual yields of each of these species are many times greater than the actual U.S. catch and show the magnitude of specific underutilized species in the U.S. zone and the potential for expanding U.S. fisheries.

Over the years the intensified use of the nation's wetlands for recreational, housing, and commercial development has been detrimental to the estuarine system in the United States. In numerous places, development has caused severe and damaging pollution of the estuarine areas.

The estuaries are significant to the fishery industry; many fish species use estuaries as nursery areas, while other species spend their entire lives in an estuarine system. Bacterial contamination, caused by untreated human sewage and storm water run-off, damages the estuaries. Estuarine oxygen resources are depleted by discharges of decomposable organic material from treated human sewage (sludge) and industrial waste. Sediment from soil erosion fills estuarine areas and smothers bottom-dwelling life forms, the source of food for many fish. Toxic material from industrial wastes, land run-off, pesticides, herbicides, and chemical manufacturing plants present a threat to the

TABLE 8 Underutilized Species of Fish

Species	1973 U.S. Catch (millions of lbs)	Estimated Annual Yield (millions of lbs)
Pollock	14	3,780
Mackerel	21	1,660
Anchovy	229	2,500
Croaker	23	1,000
Packfic Hake	3	1,000
Herring	100	3,500
Skipjack Tuna	40	2,000
Clams	100	265
Mullet	33	150
Calico Clams	1	25
Total (millions of lbs.)	564	15,880

Source: Derived from "Fisheries of the U.S., 1978." National Oceanographic and Atmospheric Administration.

survival of estuarine fish. However, while the effects of pollution and habitat degradation threaten the commercial fishery industry, environmental laws also impede it.

Environmental laws have imposed a variety of protective measures for various species and have completely disregarded the cumulative effects to other species and to the fishing industry. Some measures often have unintended and detrimental effects on the industry. For example, although the tuna industry has the only distant-water fleet, pressure exerted on the tuna industry by the Marine Mammal Protection Act has prompted U.S.-owned tuna vessels to register in foreign countries. In Hawaii there is an effort to develop the spiny-fish resource. The monk seal, which thrives on spiny fish is protected. In Oregon an increasing and protected sea lion population is preying on salmon, yet the salmon is a seriously depleted fish. As restrictions on the killing of various mammals take place, the population of the protected mammals will increase and these mammals will directly compete with man for fish.

The Immediate Future of the U.S. Fishing Industry

Despite the various factors that have inhibited the commercial fishing, there is an optimistic climate for development of the fishing industry and the exploitation of the resources available within our

200-mile zone. The National Marine Fisheries Service has estimated that an increase in the U.S. commercial catch to 8 million metric tons (almost four times the present level of harvest but less than half of the estimated potential) could yield an additional 5.6-million-metric-ton harvest for domestic consumption, lead to development of an export market, create 200,000 to 300,000 new jobs, and add between $8 billion to $10 billion to the U.S. economy. Furthermore, it could help to reverse the growing U.S. balance-of-trade deficit in fisheries products.

Two relatively recent events at the federal level have set the stage for expansion and growth of the U.S. commercial fishing industry. These include enactment of the FCMA and the more recent (May 1979) presidential announcement of a national fisheries policy, detailed below, the first ever regarding fisheries. Both of these federal actions have tended to spur interest and investment in the commercial fishing industry. Already the industry has flocked to shipyards in efforts to have new vessels built.

The FCMA extended certain fishery conservation jurisdiction of the United States out to 200 miles and promulgated advanced ideas for fisheries management. Proper management of U.S. fisheries has already curtailed the exploitation of various overutilized species by foreign countries. The FCMA also provides for foreign fishing allocations and for regulations to control and limit foreign fishing activities in U.S. waters.

Foreign fishing in U.S. waters has been declining noticeably since 1974, when foreign fleets took 3.1 million metric tons from U.S. waters. In 1976, the foreign catch was 2.6 million metric tons from the U.S. 200-mile zone. The catch was 1.8 million metric tons in 1978. Undoubtedly more fish are available to the U.S. commercial fishing industry, and the management and conservation concepts inherent in the FCMA should provide greater fish-stock stability in the future.

Furthermore, the new fisheries development policy announced by the administration on May 23, 1979, encourages the development of the fishing industry. The intent and significance of this policy has been extracted from the policy statement as follows:

> Federal policy will be to foster the development of all sectors of the U.S. fishing industry--including fishermen in our 200 mile zone, in the Great Lakes, U.S. flag distant water fleets, and U.S. processors and distributors--through a close working relationship with the industry and well-coordinated Government programs. This will involve:
>
> --facilitating industry access to private venture capital for vessels, processing plants and support facilities;

--satisfying the major fishing industry need in some regions for publicly-financed infrastructure such as ports and harbors;

--adapting existing technology and disseminating technological information to allow the industry to modernize and improve its capital facilities....

In addition, the Administration will propose fisheries development legislation to ensure funding of cooperative efforts between industry and government. It will be directed specifically toward stock enhancement, and development of the U.S. fishing industry through utilization of U.S. fishery resources, particularly those not traditionally harvested by our industry.

Conclusions

There have been various constraints on the fishing industry. For many years there was a general concept in the United States that coastal waters were no-man's land; that any nation could fish within these waters, except for a small restriction to nearby coastal waters. This resulted in the exploitation of U.S. resources by foreign fishery industries and a depletion of various species. Through the FCMA of 1976, foreign vessels have gradually been restricted from U.S. fisheries. The result is a greater fish supply to the U.S. fisherman and greater stock stability.

Another cause of the depletion of various species has been the U.S. consumer's demand for certain fish, which has lead to the depletion of the Pacific salmon and over-exploitation of lobster and oyster resources, to cite several examples.

While U.S. fleets have been active in harvesting popular species of fish, millions of metric tons of sustainable harvest of other species that are primary sources of fish food in other countries have been largely overlooked by our industry. The pollock and the cod, not to mention the squid, are favorites in many foreign countries. The federal government has recognized the potential in underutilized species and has advanced a policy to promote the development of an underutilized species market.

Other impediments to the fisheries industry include pollution and environmental controls. Pollution threatens estuaries where many species of fish spawn and feed. Environmental controls often fail to consider the fisheries industry, often driving U.S. vessels to foreign ports. Moreover, controls often fail to consider fully the overall environmental balance; the protection of the sea lion, for example, has contributed to the depletion of salmon.

Notwithstanding the above constraints and impediments, the single most significant cause in the fishing industry's failure to exploit

available resources fully has been the lack of efficient vessels. Recent trends, however, indicate substantial increases in vessel construction. Construction has more than doubled during the past five years. More significantly, however, is the trend to construction of larger and more efficient vessels. Contrary to the past, no longer is the average vessel under construction from 5 to 29 tons. Ostensibly, the surge in vessel construction reflects the optimism that the fishing industry has in the future.

Vessel construction will no doubt continue to increase to meet market demand for fish. It will increase to take advantage of the resources no longer made available to foreign fishing industries. Furthermore, because older vessels will not be able to compete adequately with new vessels entering the industry, older vessels will be taken out of the industry and replaced by new vessels, or undergo major conversions. Thus the increase in new vessels entering the fisheries industry should be impressive.

It should be noted that the problem of finding crews willing to man larger vessels that are designed to remain at sea for long periods of time may become important as the number of such vessels increases. This difficulty is met in other areas of the maritime industry and can presumably be resolved by the fishing industry within its economic constraints.

Recent government policies have augmented existing optimism in the fisheries industry. Should the newly announced policies be implemented, private venture capital for vessels, for processing plants, and for shipyards will be made accessible to the industry. Much-needed harbors and ports will be publicly financed.

The newly promulgated policy and the recent FCMA reflect a national interest in the fisheries resources of the United States. With this interest in the industry, opportunities for the maritime industry are encouraging.

The maritime industry will no doubt be met with an ever-increasing demand for vessels, drydocks, and ports and should be prepared for such demands. It should be prepared to encourage such demands and to support and promote the fisheries industry.

Recommendations

Recent policy initiatives of the federal government, combined with the provisions of the FCMA, provide the U.S. fishing industry the potential to develop actively the oceans' living resources. The goal is to protect international fisheries interests of the United States, to pursue and create new markets for fisheries products, and to develop innovative programs and concepts in order to create a healthy and dynamic U.S. fishing industry.

It is recommended that:

1. The concept that "fish is food" should drive the efforts of the federal government and industry alike to exploit the potential of U.S. fisheries.

2. The U.S. programs involving development of fisheries resources should be reorganized around market or end use potential of fisheries rather than being based on the biological availability of certain species. The emphasis must be placed on specific fisheries in the market sense, rather than on fisheries in general in the biological sense.

3. The individual fisheries that have been identified should be divided into several classes for purposes of determining what federal programs are necessary in terms of information services, research, market development, financial assistance, and biological assessment.

Class 1 fisheries, for example, might be abundant, but low value with technical preservation problems and little domestic knowledge related to the utilization. This might include as an example the pollock and pacific hake. Class 2 might be fisheries of slightly less abundance but higher in value with slightly less harvesting problems or better market acceptance, such as the herring and mackerel. Class 3 might be fish of known value that have a much lower investment risk factor than Class 1 and 2 but would require some program for technical assistance. Class 4 might be one of the established fisheries that needs only relatively minor assistance from federal sources, and Class 5 would be the fully developed or perhaps overcapitalized fishery in which the federal government should provide little or no assistance.

Once the fisheries stocks have been identified in the classes established, it should then be possible to develop programs to develop specific fisheries. As an example of how such programs might be organized, consider the following financial assistance example tailored for both shoreside and fishing activities:

1. CLASS 1 Fisheries could be partially subsidized and in addition, eligible for all types of assistance available to Class 2 through Class 4 fisheries.

2. CLASS 2 Fisheries could be eligible for low-interest loans and, in addition, eligible for all types of assistance available to Class 3 through Class 4 fisheries.

3. CLASS 3 Fisheries could be eligible for a capital construction fund and loan guarantees as well as the assistance available to Class 4 fisheries.

4. CLASS 4 Fisheries could be offered the services of Department of Agriculture and NMFS personnel.

5. CLASS 5 Fisheries would not be entitled to financial assistance of any kind.

Once the fisheries have been established in classes, it would also allow for focusing research in those areas that would promote the underutilized species (in the market sense) and would leave the research on fully developed fisheries that are economically sound to the fishing industry.

CHAPTER 5
MINING

Introduction

While recent literature has focused on the deep-seabed manganese nodule deposits as a potential mineral resource for supplementing the earth's depleting supplies of several key metals, marine mining is not limited to manganese nodules, nor should a view of U.S. maritime industry opportunities in marine mining be so circumscribed. Marine minerals in the broader sense include those derived from evaporative processes, such as recovery of salts, bromines, and iodines; placer mining of deposits that have been borne down to the coast by freshwater river runoffs; other subsea and bottom mining applications in addition to manganese nodules, such as phosphate deposits, coal deposits, and sulfides; and a variety of other metal extractive processes used for deposits in coastal areas. Products of these latter deposits include sand and gravel from dredging operations, sulfur recovered by the Frasch process, Red Sea metalliferous mud, and offshore tin and alumina as well as other potential mineral resources. Importantly, almost all of these nonmanganese nodule operations are coastal and thus offer a broader range of opportunity.

To outline the general outlook for opportunities for the U.S. maritime industry, screening criteria were developed. Mineral categories and mineral recovery processes were evaluated in terms of requirements and of the U.S. maritime industry's ability in meeting them. Included within the screening criteria are considerations of constraints and problem areas associated with the exploration and exploitation of the mineral deposit, as well as external factors such as governmental/social/economic and environmental constraints. The latter are further elaborated on in the individual sections, which discuss the potential opportunities for specific mineral resources.

Resource Opportunities Screening Criteria

A list of candidates from which maritime industry opportunities could be considered is shown in a matrix of marine mineral resource categories (Table 9). The resource categories selected as candidates

TABLE 9 Maritime Industry Opportunities in Ocean Mining

Mineral Resource	Basic Extract Tech	Location	Product Market	Science & Exploration	Marine Construction & Engr Serv.	Marine Systems Suppliers	Operations Services	R&D	Significant Potential	Remarks
Mn Nodules	Nodule Pick-up	Deep Seabed or Offshore	Ni,Cu,Co, Mn - 1985	Yes - 1980	Yes-1982	Yes-1982	Yes-1987	Yes-1980	Strong-1985 + limited Customer Base	Environmental, Legal/Political Constraints
Phosphorites	Dredging	Shelf near Offshore	Fertilizer, etc.	Yes -1980s	Yes-1980s	Minimal	Yes-1985	-	Limited market within time frame	Environmental/Legal
Sand & Gravel	Dredging	Coastal Zone inland waters near offshore	Construction materials	-	Yes-1980s	Minimal	Yes-1980s	-	Increased demand offset remote plant deposits	Environmental/Legal
Sulfur	Frasch	Coastal zone	Declining available land deposits (sour gas)	-	-	-	-	-	None	Existing Ops - Gulf of Mexico
Heavy Minerals (Placer Deposits)	Dredging	Coastal zone	Yes, gold, Ag tin, diamonds platnium	Yes-1980s	Some-1980s	-	Some Late 1980s	-	Some - Dependent on land based economics	Environmental/Legal/Technical Some existing operations in Alaska, S.E. Asia, etc.
Dissolved Minerals	Evaporative processes	Coastal inland waters	Yes	-	-	-	-	-	None	Existing operations - Pacific Coast/Gulf Salts, Mg, Bromines
Metalliferous muds & sulfides	Dredging	Red Sea offshore	Yes-Zn, Ag	Yes-1980s	Limited	Limited	Limited	Yes-1980	Very limited. Still in science mode	Environmental/current R&D limited to Atlantis II area and hydrothermal research in Pacific Basin.

are limited to the broad groupings of mineral types based on location and/or extractive process. The selection criteria from which the candidates were screened consist of a breakdown of maritime-industry opportunity subsets. To survive this initial screening, a particular mineral resource category had to have at least some potential impact on the maritime-industry sales output within the 1980 to 1990 time frame. A working definition of "maritime industries" was devised to guide the screening process.

As stated in the Introduction, we limit the term "maritime industries" to those directly involved in the commercial development, construction, and operation of marine vessels or platforms, including their navigation, positioning, and control. Excepted from the terms are basic marine scientific and technically related equipment and operations and the development, construction, and operation of "mining" equipment and systems.

While many gray areas exist in this necessarily artificial classification, and considerable technical interchange will be necessary between the two regimes, the delineation is required in order that the conclusions are kept within reasonable bounds; we wish to make the study meaningful to "classical" marine operators and not degenerate into a discussion of opportunities in the marine mining field for all aspects of the U.S. industrial complex. The subsets of the maritime industry are also limited to those segments of the maritime industry as defined in the introduction of this document. For purposes of estimating market impacts, the segments of the maritime industry were apportioned to science and exploration, marine construction and engineering services, marine systems suppliers, operations services, and research and development.

Of the categories that did not survive the initial screening, the dissolved-minerals group (salt, bromines, iodines, magnesium, and other mineral products produced or capable of being produced directly from seawater through evaporative processes) was rejected as being basically not applicable to the maritime industry in terms of the aforestated definition. While the production of such products is carried out in the coastal waters of the United States and other countries, the maritime industry interaction with the productive process is quite minimal, if present at all. The maritime transportation element of the mineral production was not considered as a unique factor generated from the mineral resource development but only one common to all industrial products. Obviously, as products of the seawater evaporative processes expand in both number of products extracted and tonnage levels per product, some impact will be felt by the maritime transportation sector. This impact will undoubtedly be handled in the traditional supply/demand reaction without any significant major offset of long-term maritime transportation trends.

Marine sulfur mining (that part of the sulfur market that is supplied by marine-based deposits) was rejected because of the lack of

any foreseeable increase in these marine operations. (Current sulfur operations from offshore deposits are limited within the United States to one or two operations in the Gulf of Mexico). While overall sulfur consumption, both domestic and worldwide, has been steadily increasing, new sources of supply have developed, such as the production of sulfur from sour gas, a by-product of stringent environmental requirements for petrochemical refinery operations and petroleum usage. As the sulfur produced from these facilities is supplemental to the operation of both natural gas and crude-oil cracking operations, it can be brought into the market without the usual cost/benefit constraints. Thus, it is improbable that additional Frasch-type platforms will be ordered for the offshore areas.

Admittedly, the general increase in sulfur usage and modification of its form into prill (pelletized), liquid, and/or other environmentally required states could have an impact on vessel requirements. The transport and transfer of sulfur in these nonconventional forms will require some modification to existing transfer equipment and also impose additional new buildings or conversions requirements for bulk carrier fleets.

The category of heavy minerals placer deposits, which was broadened to include all coastal zone and near-inshore placer sands, was rejected as being too limited in potential opportunities for U.S. maritime industry within the assigned time frame. Gold, silver, diamonds, platinum, alumina, and similar materials that are currently being produced or have potential to be produced from the coastal-water deposits are only minimal operations at this time. No long-term growth trend before the end of the century is indicated. If major technological developments occur that overcome many of the problems of working in an at-sea environment (for these materials only occur in trace percentages relative to ore-body yield) then perhaps opportunities for cutter head and ladder dredges, crewboats, workboats, and slurry systems would arise. All indications, however, are that this will not be the case.

Tin-mining operations now in progress in southeast Asia are limited to a few dredges in Indonesia and Thailand. The probability of these operations imposing requirements on the U.S. maritime industry for meeting their expansion needs is very low. The existing companies are Dutch owned and operated and have a long history of similar operations in the area. Dredging technology is highly advanced in The Netherlands, and there does not appear to be much room for U.S. dredge construction or operational services to enter this sector.

The categories that survived the initial screening include manganese nodule mining from the deep seabed, sand and gravel recovery, phosphorites dredging, and metalliferous muds. Manganese nodules mining from the seabed appears to have the potential for significant impact on the maritime industry, as defined, provided certain legal and

political constraints, further discussed in that section, can be overcome.

Phosphorites, in both near-shore nodule composition and subseabed deposits are retained as potential opportunities because of recent increased activity at the scientific research level. This research indicates that several areas including near-shore Mexican and U.S. waters contain potential reserves of commercial scale. The technology for dredging these deposits does not seem to be much different from that of sand and gravel dredging. With increased demand for phosphate-based fertilizers, economical exploitation of marine deposits appears highly probable.

Land-based sand and gravel deposits of economic resource quality are facing the possibility of being depleted within the 1980-1990 time frame, largely because land-based sources of supply are now found at marginally economic distances for transportation to the point of usage of the materials. Mostly, the sand and gravel is needed in heavy construction and building projects, which are mainly located near coastal areas. Having a readily available source of supply from coastal or offshore waters can keep prices of sand and gravel at competitive levels. There are many constraints, however, to the expansion of offshore sand and gravel operations that must be considered in the evaluation of opportunity development. These include not only the environmental aspects connected with coastal zone management but also use conflicts that could have considerable impact in determination of access rights.

Metalliferous muds (which include zinc- and silver-bearing hot brines) and metallic sulfide deposits in the offshore areas are not considered for potential opportunities because of the heavy research and development efforts needed to develop commercial-scale systems. Efforts currently under way in this resource area include pilot operations in the Red Sea that will be expanded to a major commercial-scale operation within the next five years and government-supported exploration research of hydrothermal deposits in the Pacific basin.

Metalliferous Muds

In addition to manganese nodules, other deep-sea mineral resources are those associated with metal enrichment in regions of hydrothermal activity. Only one of these is under current commercial investigation--the metalliferous muds of the Atlantis II Deep in the Red Sea. The others are in the realm of scientific studies, in the rift zones of, e.g., the Pacific Ocean. In the distant future, significant deposits of metallic ores may be developed, but for the time being they must be classified as objects of scientific investigation, not commercial development.

The sole exception, the Atlantis II Deep of the Red Sea, is currently under evaluation by Red Sea Commission, a joint effort of the governments of Sudan and Saudi Arabia. Technical support to the Commission is provided primarily by B.R.G.M., the mining/geologic research unit of the French government, and Preussag of Germany. U.S. Geological Survey personnel have been involved in some technical operations.

At present, the relatively small size of the operation, its remoteness from the United States, and the present positions of European industry indicate little opportunity for the U.S. maritime industries. Some specific U.S. technology may be drawn on. Developments of other similar resources, closer to the United States, are too far in the future to come within the purview of this study's time frame.

Sand and Gravel

While of low value per ton, sand and gravel constitute one of the major mineral industries of the United States. Current production is estimated at 937 million tons per year (U.S. Bureau of Mines Commodity Summary, 1979). Its relatively low value and general widespread distribution require that usage be rather close to the source.

Because many major metropolitan areas are located in coastal regions, nearby deposits have been used extensively for local construction. To support active construction requirements in these areas, offshore deposits now are becoming commercially interesting, within both state and federal waters. Within the United States, the most active interest is in Hawaii (for offshore construction and beach replenishment), New York, and California. In addition, an active program has been started in the Virgin Islands, where local, shore supplies of sand and gravel are almost non- existent.

Deposits have been mapped off the coasts of the United States, particularly off New England and in the Southern California Borderlands area, both close to major consuming regions. The prospective petroleum production in the Beaufort Sea has raised interest in the possible use of local gravel deposits to form artificial islands as bases for production wells. In 1975, approximately 200 dredges were engaged in commercial-scale operations for sand and gravel aggregates in U.S. waters. They recovered approximately 44,500,000 tons of materials.[1]

Several states now prohibit or severely limit marine mining for sand and gravel within their waters. The federal government has not yet established any regulatory regime for leases or permits on the Outer Continental Shelf, although such leases are within the scope of the Outer Continental Shelf Lands Act (OCSLA) of 1953 and amendments of 1978. While draft regulations were proposed in 1974, no final regulations were promulgated, and revisions in the Outer Continental

Shelf Lands Act, the National Environmental Policy Act, and the Coastal Zone Management Act will require a new start on such regulations. An interagency task force, under the direction of the Department of the Interior is currently examining the need and feasibility of proceeding with the development of federal programs to promulgate regulations and allow leasing of the federal offshore lands for marine minerals mining. Until such actions take place, marine mining of minerals within the United States is limited to those states that allow operations in their waters.

Marine sand and gravel operations exist in several other countries and areas, notably Japan and Northern Europe. The major European operations provide the primary technological competition that will face the U.S. maritime industry in any attempt to penetrate this market.

Environmental Concerns

Current inhibitions on marine mining of sand and gravel are based largely on the environmental problems associated with such mining (Table 10).[2] As can be seen from the table, there are a large number of possible adverse effects; the magnitude of many of these is still inadequately understood. It is expected that resolution of these concerns will take some time, with a concerted effort by governments and potential industrial actors required. The federal government's role and extent of activity are not yet known.

General Outlook for Opportunities

While there is still considerable activity in nearshore regions in New York, the Great Lakes, and California, reports from the Corps of Engineers, which must issue permits in navigable marine and estuarine waters, indicate increasing resistance to the issuance of such permits because of the high visibility of nearshore and estuarine operations and conflict with commercial fisheries, sport fisheries, and recreational uses of these areas.

Opportunities in the Outer Continental Shelf (OCS) regions will be nonexistent until problems in the federal regulatory process are resolved. Even then, there may be severe competition from major European firms, except for supply boat and similar activities. The application of the Jones Act (Merchant Marine Act of 1920) and its implication on U.S.-built, -documented, and -manned vessels to the OCS area is not clear as yet, but a case for its application in the U.S. exclusive economic zone probably could be made.

TABLE 10 Evaluation of Possible Effects of Marine and Gravel Hydraulic Mining

1st Orde	2nd Order	3rd Order	4th Order	Beneficial (+) or Deleterious (-)
Evacuation	Obtain sand and gravel	Broaden resource base in market area	Hold down construction costs	-
		Reduce pressures to expand onshore sources of supply	Prevent accelerated deterioration of onshore environment	+
			Prevent increase in truck traffic	+
	Change bathymetry	Leave mined-out area pock-marked with pits	Cause formation of stagnant water in pits	-
		Alter beach profile	Cause beach slump	-
		Alter wave refraction pattern	Cause coastal erosion	-
		Alter littoral sand budget		
		Chance migration patterns	Harm fishery	-
	Expose boulders	Snag bottom trawls, etc.	Increase fishing expense	-
		Provide hiding areas for organisms	Improve fishing	+
		Provide attachment surfaces for organisms	Increase food supply	+
	Remove Substrate	Destroy benthos	Harm fishery	-
		Destroy spawning ground	Inhibit repopulation	-
	Penetrate fresh water aquifer	Cause discharge of fresh water	Lower onshore water table	-
			Cause saltwater encroachment	-
Discharge plume	Discharge fine sediments at surface	Directly affect marine organisms, including juveniles and larvae	Introduce pollutants	-
			Harm filtering structures	-
			Harm respiratory structures	-
			Decrease feeding efficiency	-
		Reduce light level in water column	Reduce photosynthetic production	-
		Increase surface area for bacteria	Reduce O_2 level	-
		Create turbidity	Effect unpleasant appearance	-
	Discharge bottom water at surface	Introduce heavy metals	Harm marine organisms	-
		Introduce nutrients	Encourage plant growth	-or-
Blanket of fines	Smother benthos	Harm fishery		-
	Inhibit recruitment			
	Smother algae	Reduce food supply		-
	Change character of substrate	Interfere with feeding	Reduce population and/or alter migration patterns	-
		Interfere with locomotion		
		Foul respiratory surfaces		
		Reduce likelihood of larval setting or metamorphosis		
		Recruit new communities		-or-
	Smother vegetation	Cause soil to destabilize	Redistribute soil where not wanted	-
	Smother coral	Lose habitat		-
	Deposition unwanted areas	Fill navigation channels		-
		Alter coastline		

Source: Swateck, Paul, 1975, "A Conservationist's Perspective on the Prospect of Nearshore Sand and Gravel Mining." Workshop on Environmental Affects of Submarine Mining. Committee on Minearl Resources and the Environment, NRC, Washington, D.C.

Manganese Nodules Mining

In recent years, considerable attention has been focused on the deep-seabed manganese nodules deposits as a potential source of supply for several metals critical to U.S. needs. While the existence of such deposits has been known for over a century, little interest in exploration and exploitation of such deposits was evidenced because technology for locating and winning these resources was not available. With the expansion of offshore oil and gas activities and the subsequent development of deep-ocean engineering and supporting technologies, the attraction of a vast mineral deposit in the deep seabed passed from a scientific curiosity to that of a potentially important commercial opportunity. The United States, whose industrial might is now threatened by energy shortages and higher costs of energy and alternative energy source development, is also building up toward a materials shortage. U.S. imports of minerals supplies, particularly those that are critical to our economic and defense needs, are approximately $10 billion annually, with the major amounts of materials coming from what could be considered uncertain sources of supply (See Table 11). By the end of this century, the U.S. balance-of-payments trade deficit for such materials may be in excess of $100 billion in current year dollars. Given this scenario, there have been significant efforts during the past 15 years by the private sector to develop necessary technologies to win these resources. There are currently five active international consortia, of which four have major participation by U.S.-based companies (see Table 12).

The purpose of these several organizations has been to locate deposits in the Pacific nodule belt capable of sustaining commercial scale operations (2 million to 3 million tons/year) for a period of 20-25 years. The deposits will be mined chiefly for their nickel content. However, the copper and cobalt contained in the feedstock and, in the case of one of the consortia, manganese and possibly molybdenum will be recovered. In addition to exploration and basic ocean research activities in the nodule belt, development work has been progressing on miner system design, lift system, platform design, and extensive laboratory research into beneficiation and refining of the recovered seabed materials into end products.

To date, all the consortia in which U.S. companies have interests have had test-scale mining devices at sea for proof-of-concept tests. The scale of these devices was from 1/8 to 1/5 commercial scale in terms of tonnage throughput to the lift systems. The vessel/platform configurations used were converted drill ships or, in one case, a converted ore carrier, equipped with dynamic positioning systems, heavy lift, and gimbal heave compensation systems and pipe-handling equipment. The tests did demonstrate proof of concept of mining but did not demonstrate, nor was it the intent of the test programs to assess, reliability or extent of operations of these systems.

TABLE 11 U.S. Net Import Reliance of Selected Minerals and Metals as a Percent of Consumption in 1978

MINERALS AND METALS	NET IMPORT RELIANCE* AS A PERCENT OF APPARENT CONSUMPTION**	MAJOR FOREIGN SOURCES (1974-1977)
COLUMBIUM	100	BRAZIL, THAILAND, CANADA
MICA (sheet)	100	INDIA, BRAZIL, MADAGASCAR
STRONTIUM	100	MEXICO, SPAIN
MANGANESE	97	GABON, BRAZIL, AUSTRALIA, SOUTH AFRICA
TANTALUM	97	THAILAND, CANADA, MALAYSIA, BRAZIL
COBALT	95	ZAIRE, BELG.-LUX, ZAMBIA, FINLAND
BAUXITE & ALUMINA	93	JAMAICA, AUSTRALIA, SURINAM
CHROMIUM	91	SOUTH AFRICA, U.S.S.R., TURKEY, SOUTHERN RHODESIA
PLATINUM - GROUP METALS	90	SOUTH AFRICA, U.S.S.R., UNITED KINGDOM
ASBESTOS	85	CANADA, SOUTH AFRICA
TIN	79	MALAYSIA, BOLIVIA, THAILAND, INDONESIA
FLUORINE	76	MEXICO, SPAIN, ITALY, CANADA
NICKEL	76	CANADA, NORWAY, NEW CALEDONIA, DOMIN. REP.
ZINC	66	CANADA, MEXICO, AUSTRALIA, BELG.-LUX.
POTASSIUM	64	CANADA, ISRAEL, FED. REP. OF GERMANY
MERCURY	64	ALGERIA, CANADA, SPAIN, MEXICO, YUGOSLAVIA
CADMIUM	63	CANADA, AUSTRALIA, BELG.-LUX., MEXICO
TUNGSTEN	56	CANADA, BOLIVIA, PERU, THAILAND
GOLD	53	CANADA, SWITZERLAND, U.S.S.R.
SILVER	48	CANADA, MEXICO, PERU, UNITED KINGDOM
SELENIUM	43	CANADA, JAPAN, YUGOSLAVIA
TITANIUM (ilmenite)	42	CANADA, AUSTRALIA
BARIUM	38	PERU, IRELAND, MEXICO
VANADIUM	36	SOUTH AFRICA, CHILE, U.S.S.R.
GYPSUM	33	CANADA, MEXICO, SPAIN
IRON ORE	29	CANADA, VENEZUELA, BRAZIL, LIBERIA
IRON & STEEL SCRAP	(19) NET EXPORTS	
ANTIMONY	23	SOUTH AFRICA, BOLIVIA, CHINA, MEXICO
COPPER	20	CANADA, CHILE, PERU, ZAMBIA
IRON & STEEL PRODUCTS	12	JAPAN, EUROPE, CANADA
SULFUR	12	CANADA, MEXICO
ALUMINUM	11	CANADA
SALT	10	CANADA, BAHAMAS, MEXICO
LEAD	9	CANADA, MEXICO, PERU, AUSTRALIA
CEMENT	8	CANADA, NORWAY, BAHAMAS, MEXICO, UNITED KINGDOM
PUMICE & VOLCANIC CINDER	4	ITALY, GREECE

*NET IMPORT RELIANCE = IMPORTS-EXPORTS + ADJUSTMENTS FOR GOV'T AND INDUSTRY STOCK CHANGES

**APPARENT CONSUMPTION = U.S. PRIMARY + SECONDARY PRODUCTION + NET IMPORT RELIANCE

REVISED SEPT. 1, 1979

Source: Bureau of Mines, U.S. Department of the Interior (Import-Export data from Bureau of the Census).

TABLE 12 Ocean Mining Consortia

1. OCEAN MINING ASSOCIATES (O.M.A.) (a Virginia partnership)
   - Deepsea Ventures Inc. (a subsidiary of Tenneco Inc. (USA) and service contractor to the Consortium)
   - Essex Minerals Co. (a U.S. Corporation owned by United States Steel Corp) (USA)
   - Sun Ocean Ventures (a U.S. corporation owned by Sun Co. Inc) (USA)
   - Union Seas Incorporated (a U.S. subsidiary of Union Miniere S.A' Belgium)

2. OCEAN MANAGEMENT INCORPORATED (O.M.I.)
   - International Nickel Company of Canada Ltd. (INCO)
   - SEDCO Incorporated (USA)
   - A.M.R. Group of the Federal Republic of Germany
   - The Deep Ocean Mining Company of Japan (DOMCO Ltd.)

3. OCEAN MINERALS COMPANY (O.M.C.)
   - Ocean Systems of Lockheed Missiles and Space Company Inc. (USA)
   - Amoco Minerals Co. (a subsidiary of Standard Oil Co. of Indiana) (USA)
   - Billiton International Metals B.V. (a subsidiary of the Royal Dutch/Shell Group) (Netherlands)
   - Bos Kalis Westminister (Netherlands)

4. THE KENNECOTT GROUP
   - Kennecott Copper Corp. (USA)
   - Rio Tinto Zinc Deep Sea Enterprises Ltd. (U.K.)
   - British Petroleum Minerals Ltd. (U.K.)
   - Consolidated Goldfields (U.K.)
   - Noranda Mines Ltd. (Canada)
   - Mitsubishi Corp. (Japan)

5. ASSOCIATION FRANCAISE POUR L'ETUDE ET AL RECHERCHE DES NODULES AFERNOD (FRANCE)
   - Centre National pour l'Exploitation des Oceans (CNEXO)
   - Commissariat a l'Energie Atomique (CEA)
   - Societe le Nickel (SNL)
   - Chantiers de France-Dunkerque (from the Empain Schneider Group)

Since the completion of these tests, the consortia have reduced their at-sea efforts to continuation of exploration and prospecting and have continued laboratory and pilot-plant-scale processing research. Predicted time frames for commercial operations of these several consortia are difficult to assess in light of the several external constraints to manganese nodule mining. These are discussed in greater

detail below. The effect on opportunities for the U.S. maritime industry is dependent on the development schedule of the existing consortia operators. Projected plans call for continued exploration activities and R&D in processing techniques. Scale up for the mining elements, vessels, and full-scale process-plant subsystems, however, which will require investment capital in the order of $800 million to $1 billion per consortium will not be considered until several of the legal and political constraints discussed below are resolved. The direct effect on the maritime industry has been analyzed above. It is the best estimate of the committee that no commercial operations will begin until the late 1980's at the earliest, given favorable resolution of these constraints. *The illustrations (D, E, F, G, H) on the* following pages, courtesy of the Ocean Minerals Company, depict the vessels and system for mining the seabed.

Constraints to Manganese Nodule Mining Development

As with most fledgling industrial endeavors of a high technology nature, there are constraints in ocean mining development as well. The difference in the case of the manganese nodule development, however, is one of magnitude of the constraints particularly in the legal and regulatory areas. Establishing complex legal regimes and environmental and operational regulations prior to the development of an economically viable industry could result in further delay of the industry's expansion to commercial-scale activity.

A need is recognized by the ocean mining industry for a stable legal environment that will encourage the industry's development and will enjoy the necessary regulatory flexibility t[illegible] et changing technical, environmental, and economic conditions.

Technical

Test data to date have definitely proven that mining nodules from the deep seabed is technically feasible. Laboratory bench-scale process development has also shown that reasonable recoveries of Ni, Cu, Co, and, where so required, Mn product, can be effected by both pyrometallurgical and hydrometallurgical means. Prospecting and exploration activities using off-the-shelf and modified equipment have also proven satisfactory for the level of operations. Vessel subsystems, basically adopted and modified from the offshore drilling industry, have been of adequate scale and capabilities to support development testing. It is when the program is expanding toward commercial configuration development that several technical issues arise that must be resolved prior to establishing full-scale operations. These issues or technical challenges can be considered

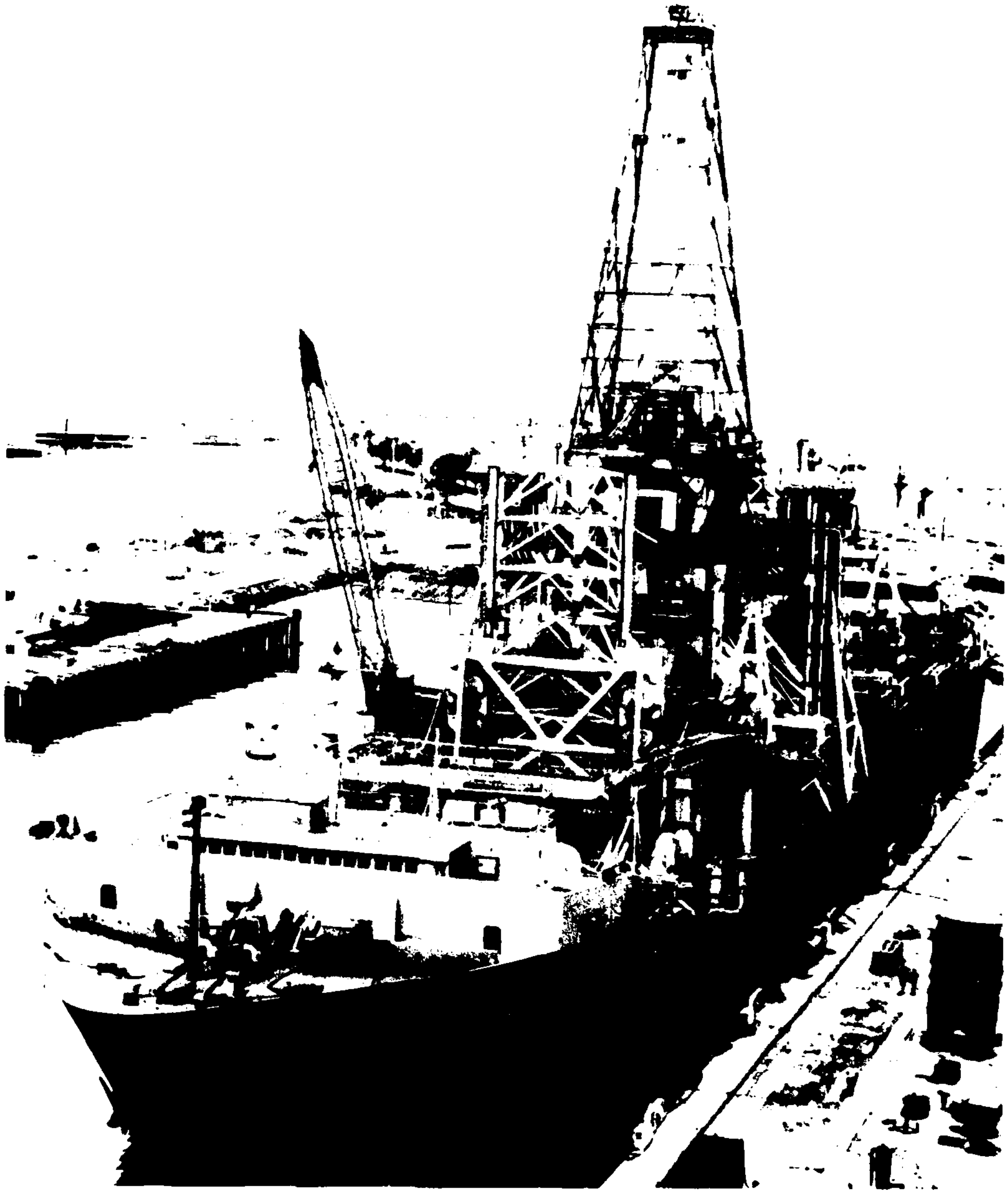

ILLUSTRATION D Outfitting of GLOMAR EXPLORER

Source: Ocean MInerals Company

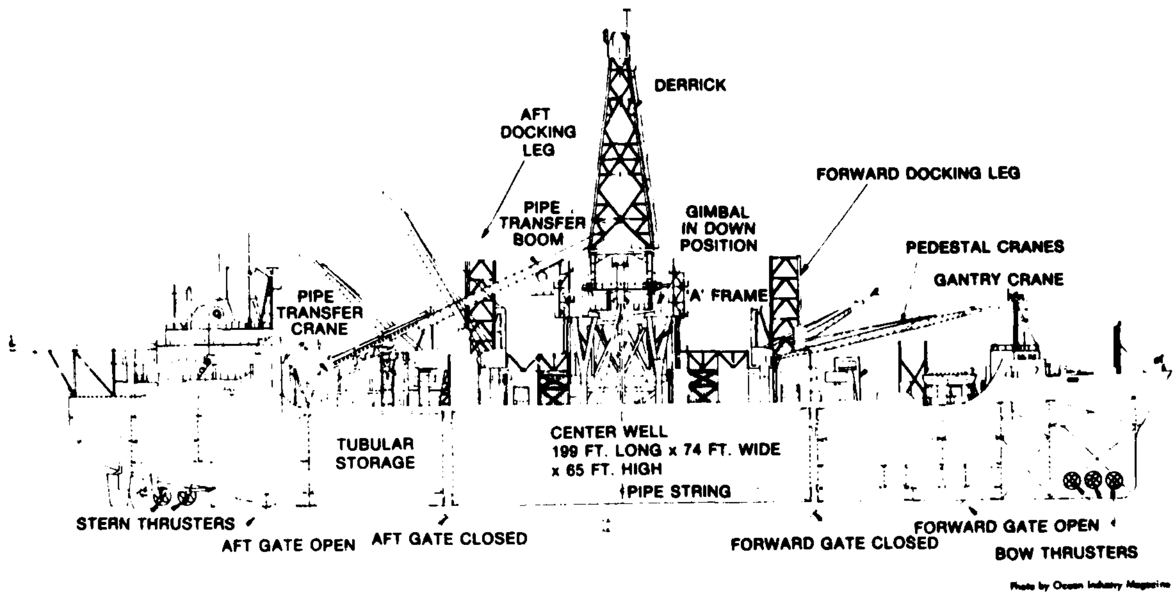

ILLUSTRATION E Key Features of GLOMAR EXPLORER

Source: Ocean Minerals Company

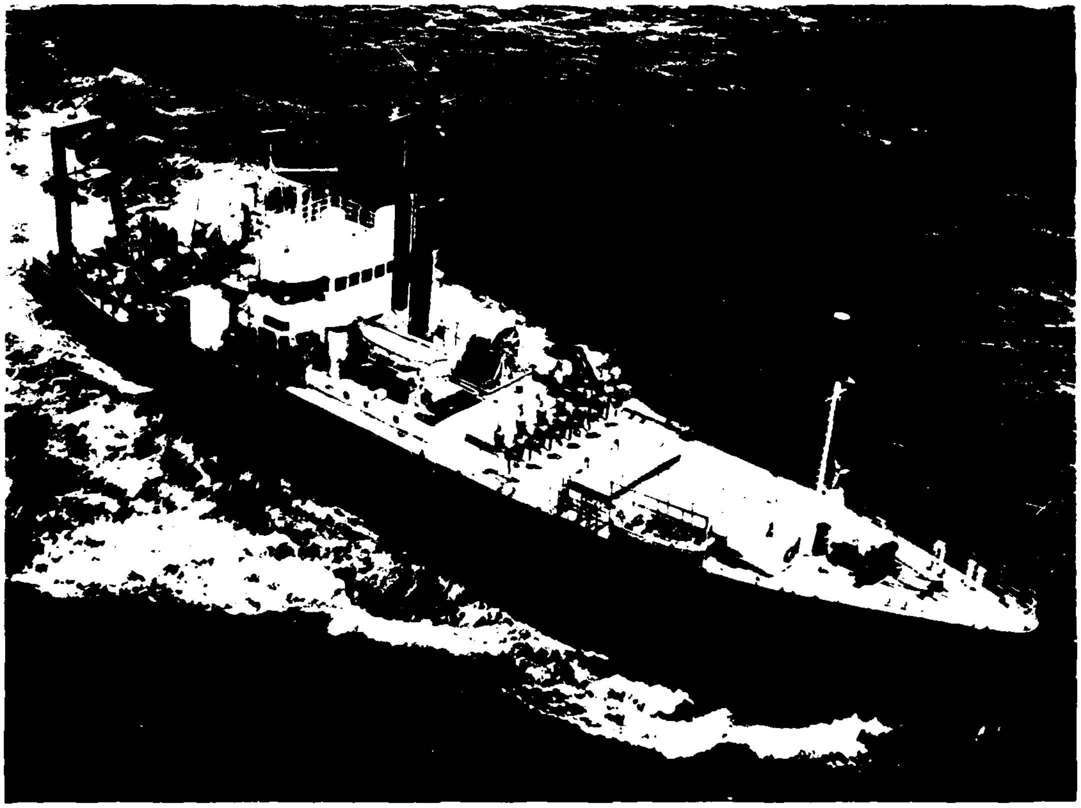

ILLUSTRATION F Oceanographic Vessel GOVERNOR RAY

Source: Ocean Minerals Company

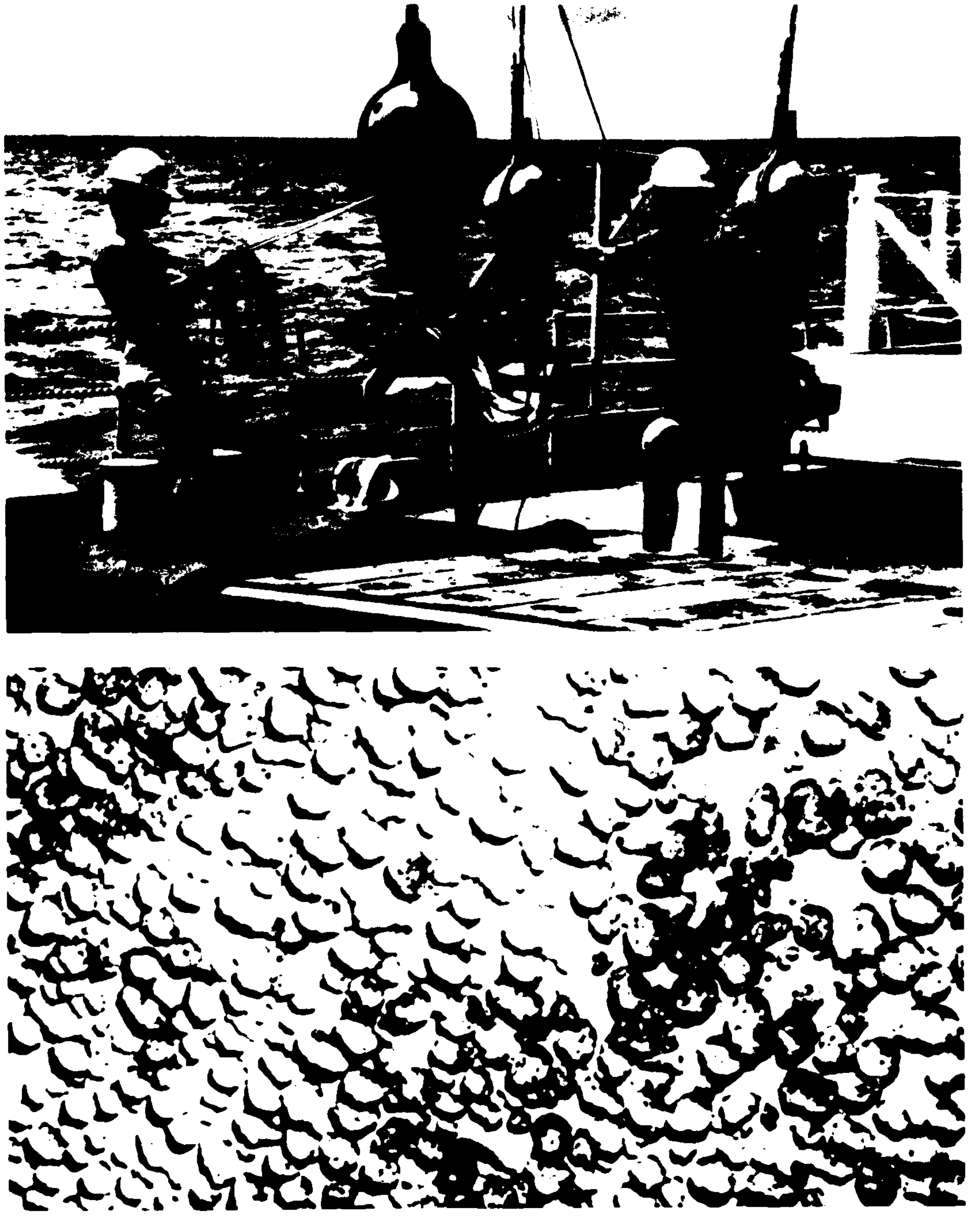

ILLUSTRATION G Recovery of Mineral Modules

Source: Ocean Minerals Company

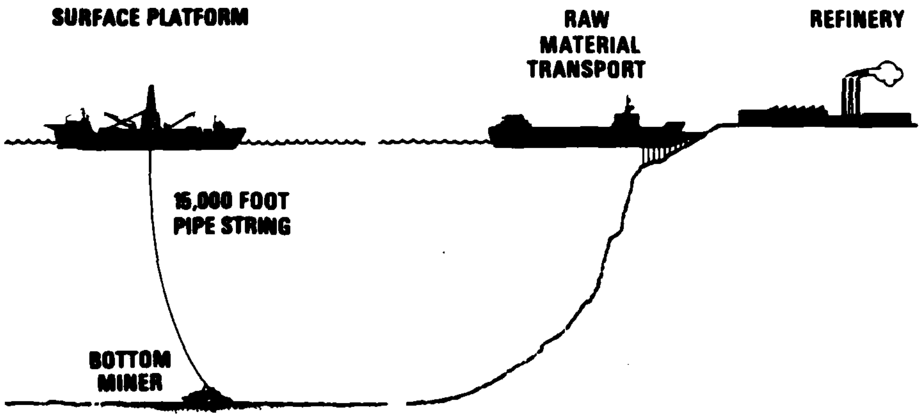

ILLUSTRATION H Manganese Nodule Mining and Processing System

Source: Ocean Minerals Company

from the point of view of the major subsystems that make up an integrated mining operation:

(a) Prospecting and exploration--need exists for more rapid collection of bottom data, collection of topographic data, nodule abundance, nodule quality, and seafloor geology. Current techniques are of low accuracy, are time consuming, and do not give adequate assurance that bottom-soil conditions and mine-site mineability will be replicative during commercial operations when scaled from the prospecting data. Current exploration and ocean research vessels in use have not been specifically designed for nodule work and therefore do not have optimum operating characteristics.

(b) Mining system--To date, tests have had only sustained operations of several hours without a requirement for some system adjustment or shutdown for repairs. Need exists for high-reliability components, and long-term trouble-free operations at depths of 15,000-17,000 feet (4570-5180 m). Lift systems that will require pipe diameters of 20-30 inches (50-75 cm) will also impose severe loads on vessel handling equipment and ship dynamics. To date, lift systems tested have been on the order of 6-9 inches (15-22 cm) diameter. Large quantities of nodules, on the order of 10,000-20,000 tons, will have to be recovered. During the activities to date, only some 2000 tons at most have been recovered with test mining devices.

(c) Vessel systems--The scaling up to commercial mining vessels from existing test ships to those of 100-150,000 DWT vessels poses some formidable challenges to vessel designers and operators. The mining vessel must be able to stow and handle over 3 miles (4.8 km) of 20-30-inch (50-75-cm)-diameter lift system pipe, tow the lift system and mining devices at slow speeds (<3.0 kts) over an exact mining site path during a variety of weather and sea conditions, be able to transfer large quantities of slurried nodule materials while under way to transport vessels, transfer personnel and equipment, be basically self-sustained for long periods of time without shipyard support (four years), and have adequate buffer storage aboard for nodule materials, pending delayed arrival of transport vessels. The problem of providing dynamic positioning capability for commercial operations is an order of magnitude above what is currently available. The largest dynamicaliy position (DP) capable vessel constructed to date is the GLOMAR EXPLORER of 36,000 DWT. Other existing drillships having DP capability are all on the order of 10,000-16,000 DWT.

(d) Transport vessels--While little developmental work will be needed in basic transport vessel hull and propulsion design,

it is apparent that considerable attention will be paid to slurry transport and transfer systems. Currently, only one fully equipped (load and discharge) and some four to five partially equipped (load only) slurry vessels are operating in the world's fleets; these are configured mainly for iron-ore pellet carriage. The transport vessels must also be capable of transfering from the mining vessel, at very low maneuvering speeds, large volumes of mined materials and also have transfer capability for other cargoes of general and specialized nature as well. Because of the importance of keeping buffer storage requirements aboard the mining vessel to a minimum, the reliability of arrival schedules and transfer of the mined nodules to the transport vessels is paramount. Highly accurate navigation and control systems and low-maintenance downtimes will be requirements to be imposed on the transport fleet.

(e) Processing Plant--While not a direct impact on the U.S. maritime industry, the ability of the deep-seabed mining industry to solve several critical technical processing issues could be a pacing item in the development. The decision on whether to extract three minerals (Cu, Co, Ni) or four minerals (Cu, Co, Ni, and Mn) is a driving factor in selecting a particular process. In order to reach a decision on capital investment for a process plant, a pilot-plant operation must be studied for some period of time. At a minimum, at least eight months to one year of pilot-plant operations would be required to prove the various process circuits and flow-sheet configurations prior to making the necessary $350 million to $500 million investment that a process plant of commercial size would represent. If the assumption is made that a pilot plant would operate at a nominal 50-100 tons of feedstock per day throughput, then at a minimum some 10,000-20,000 tons of dry nodules would be required for the pilot-plant operation. To date, the combined inventory of nodules obtained by all consortia from the several test programs is less than 2000 tons. Supporting the consortia's efforts over the next several years to gather these nodules could have an impact on the vessel operating services of the U.S. maritime industry.

Environmental Constraints

The technical constraints outlined above can be resolved in the 1980-1990 time frame by a well-planned test and development program by the several active ocean-mining- system developers. Environmental problems of ocean mining could be of broader scope and could retard development of commercial systems for the near future. The extent of damage to benthic organisms as a result of mining-device contact with the sea bottom has been the focus of efforts by the Deep Ocean Mining Environmental Study (DOMES) program of the National Oceanic and

Atmospheric Administration (NOAA) during recent (1977, 1978, 1979) tests of mining operations. Results to date do not indicate significant effect; however, the tests were of limited periods and conducted in limited areas that may not be representative of either the extent of commercial mining operations or the benthic communities to be encountered in the actual mining sites. More work will be done in this area by both the systems developers and federal government agencies.

The fate and effects of benthic plumes as a result of disturbing the bottom sedimentary layer during mining operations was also studied during the DOMES program. The effect of such plumes was found to be minor, and, even in commercial-size systems, the effect does not appear to be significant. Surface discharge of nodule fines and slurry was also studied and based on the limited data did not pose any environmental threat to living resources or the water column characteristics at any significant distance from the discharge outlet. Additional study will be performed in this area during further test operations, when dispersion patterns and correlations with depth will be more thoroughly examined.

The major environmental issue that will probably fall out of commercial development of a deep-ocean mining industry will be disposal of tailings from beneficiation and refining of the nodules. Disposal on land in conditions similar to those used in existing mining and refining operations appears to be extremely costly and in some cases, depending on process techniques, poses potential problems to surrounding environments. Disposal of process spoil at sea, which could be far more economical and safe from an environmental point of view, will require additional study and analysis. The mechanisms of reject materials mixing with the water column, sedimentation rates, and the effects on living organisms of suspended metals and solutions are determined by complex biological, chemical, and physical interrelationships. Industry, academic, and public sector-scientists will be working together to study the phenomena of process rejects disposal, and this will be an important factor in the overall industry development schedule.

Economic Constraints

As in any natural-resource venture, a key constraint on timing the development is that of market demand and market price. Current metal markets, which have shown either some lack of movement or a decline in consumption as a result of downward pressures on steel production, because of energy source fluctuations, are beginning to establish their traditional upward trends. Of specific impact on the deep-seabed minerals is the realization that any major effort to develop and utilize alternate energy sources to fossil fuels will require increased amounts of these metals specifically produced from the nodule feedstock, i.e., nickel, cobalt, copper, manganese, and molybdenum. The current oversupply of nickel will diminish in the near term and

those large-scale mineral projects that have been placed on the shelf because of a lack of market opportunity will undoubtedly be reopened. The cost trade-offs between a major new nickel mining development, for example, in a remote, lesser-developed country is beginning to be seriously contended by deep-seabed mining systems, given the assumption that the technical and environmental issues are suitably resolved. The effect on the U.S. maritime industry as a result of economic constraints to deep-seabed mining is a critical one and could determine the rate of growth and opportunity for our shipyards, suppliers, and service organizations within the time frame of interest.

Political/Legal Constraints

Of all the previously outlined constraints, the issues raised by the political/legal aspects are by far the most critical and have the longest-term effect on the ultimate form and rate of growth of a U.S.-based deep-seabed mining industry. The international legal uncertainties stemming from the protracted negotiations within the Third United Nations Conference on the Law of the Sea (UNCLOS III) present a paradigm of legal uncertainties impacting adversely on commercial development. The basic problem is one of disagreement internationally as to the legal rights to the mining of deep-seabed resources in areas beyond the continental margins (or areas of national jurisdiction).

The United States has been engaged for more than a decade, first within the U.N. Seabeds Committee and, second, beginning in 1973 at the Third United Nations Conference on the Law of the Sea (UNCLOS III), in negotiating access rights to the resources of the deep ocean floor. The United States has agreed that such resources are the common heritage of mankind but has insisted that that principle should be developed through a clear specific convention assuring access to seabed resources. Although a rather successful meeting of the conference occured last summer in Geneva, the basic problem still centers on achieving a balanced development system; one that would provide assured access to one half of all the seabed sites, while the other half would be developed by an international enterprise operating through joint ventures or similar arrangements. Continued disputes in the negotiation relate to the machinery for assuring access, financing, technology transfer provisions, review clauses, decision-making structures, and other issues. Because of the impasse which was faced in these discussions, the U.S. Congress passed legislation which was enacted into law on 28 June 1980, which authorized sea-bed mining on an interim basis pending successful conclusion of a Law-of-the-Sea Treaty. Similar legislation has been passed by the Federal Republic of Germany and is under consideration by the United Kingdom, Belgium, France, and Japan. In turn, spokesmen from developing countries have strenuously objected to such proposed legislation, claiming it to be illegal under their interpretation of certain UN resolutions, and their view of the Law-of-the-Sea negotiations. The United States and other developed nations have refused, however, to accept such a moratorium on seabed

mining and have insisted that such mining is a lawful use of the high seas available to any nation.

Projections of Opportunities for the U.S. Maritime Industry

At the outset, it must be realized that current organizations active in the of development of deep-seabed mining systems are multinational despite the fact that four of the five groups are headquartered and operated as U.S. companies. The percentage of combined U.S. ownership in these four consortia varies from as high as perhaps 75 percent to a bare 25 percent. Such expenditures as the consortia will make over the next two years in development, test, and capital equipment investment will depend heavily on the ability to satisfy their multinational boards of directors that the several technical/environmental/economic and political/legal issues do not pose problems toward the goal of commercialization. Also, it must be proven that orders placed with U.S. maritime industry suppliers of goods and services are in the best interests of the particular organization.

The non-U.S. partners to these ventures (Table 12) include companies from the United Kingdom, France, Canada, Belgium, Japan, West Germany, and The Netherlands--countries that have extensive maritime-oriented industrial complexes and a long background of competing actively in the ocean industry market. This will pose several problems of not insignificant merit for the U.S.-based maritime industry. A significant amount of business for the U.S. maritime industry could be considered should the four consortia, currently operating as U.S. companies, continue to do so under what they would perceive as favorable aspects of a U.S. deep-seabed-mining legislative act. These include possibilities such as Title XI Mortgage Guarantees, Operating Differential Subsidies, and Construction Differential Subsidies as provided by the Merchant Marine Act of 1936, as amended.

Some of the opportunities for the specific segments of the industry and forecasts of a rough order-of-magnitude impact are discussed below. Table 13 represents a rough order-of-magnitude manganese nodule mining implementation schedule and expenditure projection for specific segments of the U.S. maritime industry.

Science and Exploration

The activities in prospecting and exploration of potential mining sites are currently under way. Most consortia conduct several cruises per year to gather data on bottom soil conditions, abundance and quality of nodule resources, water column characteristics, and general site-specific oceanographic data required to support claims and environmental assessments. To date, most of the science and exploration activities have been carried out with small- to medium-sized research vessels or converted trawler-type R/V hulls and have not implemented high-resolution sonic mapping and analytical tools such as have been developed for offshore oil and gas exploration.

TABLE 13 U.S. Maritime Industry Opportunities Manganese Nodules - Deep Seabed Mining
(Millions of dollars - 1979 Constant)

ACTIVITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
SCIENCE AND EXPLORATION	5-10	10-15	10-15	10-15	10-15	10-15	10-15	5-10	5-10	5-10	80-130
MARINE CONSTRUCTION AND ENGINEERING SERVICES	20-30	50-70	100-200	200-300	200-300	200-300	200-300	100-200	100-200	100-200	1270-2100
OPERATIONS SERVICES	-	-	-	-	20-50	50-100	100-200	200-300	300-500	300-500	970-1650
RESEARCH & DEVELOPMENT	5-10	5-10	10-20	10-20	10-20	10-20	5-10	5-10	5-10	5-10	70-140
TOTAL	30-50	65-95	120-235	220-335	240-385	270-435	315-525	310-520	410-720	410-720	2390-4020

With pending U.S. legislation providing an incentive for additional exploration activities and the fact that any international treaty will probably incorporate provisions for a "banking" system (i.e., contractor explores two sites and then is allowed to exploit one of them), the pressure to have accurate and rapid exploration data will increase. Since the existing vessels are somewhat outdated, there is every reason for U.S.-based commercial research vessel owners and operators to examine their opportunities for providing services in the immediate future for the existing consortia. Improved handling equipment for retrieving samples and analyzing them onboard, more accurate means of measuring bathymetry patterns and bottom-soil characteristics, and other in situ measuring and analytical means will be needed. The scope of such activities within the 1980-1990 time frame given for the four U.S.-based consortia demands could be approximately $10 million to $15 million annually (constant 1979 dollars).

Marine Construction and Engineering Services

Increased activity in this sector above current levels within the 1980-1990 time frame is highly dependent on the legal/political situation as well as the ability of U.S. maritime industry groups to meet foreign competition in terms of newbuildings and conversion pricing. Assuming that the four U.S.-based companies are assured that their major commercial system investments will be protected by some legal regime, one can then anticipate orders for perhaps four mining vessels and at least 8-10 transport vessels during this time period. The predesign and contracting activities for these vessels will be needed in the early 1980's in order that construction can be completed and tests of systems operations proven prior to commercial operations in late 1987-1988.

If the companies operate under proposed U.S. legislation, then every mining vessel and at least one of each transport vessel for each operation will be required to be built and documented under U.S. flag. This will assure the development of the industry in U.S. maritime facilities. Given that each mining vessel will be in the 100-150 thousand DWT category, and the transports will probably be of modified Panamax-type bulkers, a total potential market for U.S. shipyards to support this requirement could be as much as $1 billion to $2 billion over the next 10 years. The industry will have to develop improved pipe-handling systems, heavy lift gear, dynamic positioning and propulsion methods, transport and transfer at-sea capability of a variety of materials including extensive slurry capabilities, long-term reliability systems, and reduced maintenance concepts to allow uninterrupted operations at sea for long periods of time and other innovative means for satisfying the needs of the deep-seabed miners. These latter activities will be required to be undertaken not only by the basic U.S. shipyard and supporting maritime suppliers but also by close cooperation with high technology systems developers in navigation

and control, propulsion technology, materials sciences, computer applications, electronic systems, and personnel habitability and operating systems.

Operations Services

The traditional maritime industry suppliers of operations services such as time and voyage charter services, maintenance and repair services, and operation of drill ships and platforms will have several opportunities for providing similar services to the deep-seabed mining industry. The marine aspects of exploration and science programs can have some immediate impact on these service suppliers. Operation and maintenance of commercial systems, however, will be paced by the rate of development of commercial systems, which in turn will be a factor of the technical/environmental/economic and political/legal aspects of the industry. At best there could be some effect in the late 1980's as the systems that are being constructed will be gearing up for their personnel and operating needs. The transport of the mined material as well as resupply of the mining vessel with consumables and personnel rotation is also an opportunity for suppliers of such services, provided they will be in a position technically to provide such services. Transport vessels will require a higher degree of operational reliability than currently expected from the bulk carrier trade. They will also require some maneuvering capability to effect under way transfer and/or replenishment operations in an efficient and rapid manner. Environmental aspects of mining and processing, particularly related to disposal of materials, might have additional influence on the suppliers of such services. The combined value for these services, beginning toward the latter part of the decade, is estimated to be $300 million to $500 million annually (1979 constant).

Research and Development

The R&D effort addressed here is strictly related to helping the U.S. maritime industry to provide the basis for being the suppliers for this new industry. As stated above, much more work is needed in areas of propulsion, dynamic positioning, navigation and control equipments, materials handling, transfer and transport techniques, and maintenance and reliability of subsystems to assure that the deep-seabed mining industry can be a viable one. With a potential of $1 billion to $2 billion in construction investment, and some $10 million to $15 million annually for science and exploration and possibly $300 million to $500 million of operating costs annually it would certainly appear that expenditure of funds in the immediate time frame for R&D would be a useful undertaking on the part of the industry. Federal government activities in this area have been somewhat limited to environmental effects (DOMES) and economic and technical studies of site selection and legal aspects of manganese nodule mining. Because of much of the nature of the individual consortia's mining and processing techniques

being of a highly proprietary nature, they have uniformly avoided the requesting or the acceptance of any governmental support other than cooperating in the aforestated areas of current government sponsored projects. Projecting a 2-5 percent expenditure as being reasonable for R&D, some $10 million to $20 million annually can be estimated for the industry.

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CHAPTER 6
OCEAN SPACE

Introduction

As the committee considered its assignment and the meaning of "ocean resources," it became evident that the space provided by the ocean was in itself a resource and presented certain opportunities for the maritime industry. In a sense, "ocean space" became the catch-all category in which uses not specifically fitting into more precise categories (such as extractive industries) would fall. Seven "ocean space" uses that seemed capable of providing maritime industry opportunities were identified; four are included in this report.

- Offshore Ports--This use of ocean space has several features that warranted its inclusion in the report. First, although there are no offshore ports (deepwater ports) in the United States at present, one is currently under construction off the Louisiana Coast (LOOP) and at least one more could be built in this century. Secondly, they represent a substantial ocean industry opportunity primarily using U.S. industry expertise gained in offshore oil development.

- Disposal Areas--The use of the oceans for disposal of materials is a subject of considerable interest in the United States. The oceans are now used for disposal of dredged material and certain wastes. Since the vehicles needed for transporting these materials would be built and operated by the maritime industry, the committee chose to treat the subject in the report.

- Enforcement and Safety--The increasing use of the ocean and ocean space along with new and proposed legislative initiatives indicates that enforcement and safety activities will be a growth area for the maritime industry.

- Research--Total national activities related to ocean research have grown steadily in post-World War II years (especially during the 1960's) and particularly through the initiation of new federal agencies. However, funding available for seagoing research and replacement/addition of vessels has fallen behind the rate of inflation. Vessels and equipment for ocean resources are developed,

constructred, and operated by the government, academia, and the private sector. Construction, repair, and some operational activities will provide increased opportunity for the industry if government funding trends in this area go into a positive mode.

The three ocean space related items considered, but not included, are the following:

• Navigation and Shipping--Clearly, the pre-eminent use of ocean space is for commercial shipping. Dealing with this use would have necessitated an examination of the future of shipbuilding in the United States and current and proposed policy affecting the U.S. merchant marine. The committee found this beyond the scope of its resources and also found much existing literature on the subject.

• Industrial/Municipal Service Platforms--Recent events have shown that several types of ocean platforms for industrial uses are clearly viable. The shipbuilding firm of IHI in Japan recently constructed a pulp mill on a barge, subsequently towed to Brazil, where it was moored and placed into operation. Vancouver Shipyards in British Columbia, Canada, launched a 204 ft x 60 ft barge in early 1979 for use as an offshore fish-processing plant, and the Swedish shipbuilding company Karlskrona Shipyard was proposing to build a $450 million power plant to float above North Sea gas deposits.[1]

These three recent examples illustrate the variety of possibilities for the maritime industry in providing fixed or floating service platforms. Other examples are provided in Tables 14 and 15, prepared by SEMA Marketing of France, indicating 17 operational floating/floated processing plants as of March 1979. However, the committee was unable to find that there would be major U.S. shipyard work on industrial plant vessels or platforms in the 1980-1990 time frame. Only after a thorough evaluation of concepts and development studies (some of which are now being undertaken by the U.S. Maritime Administration), can we evaluate the range and magnitude that this type of activity will have on the U.S. maritime industry.

• Recreation--It is clear that recreational boating is growing in the United States and that boat building constitutes a sizable and growing economic activity for boatbuilders and certain communities. However, the committee decided that small boatbuilding, while properly a part of the maritime industry and presenting a considerable opportunity for business enterprise, is not new, and, like ocean transportation, does not fall within the guidelines of this study. This is because the recreational resources of the oceans are recognized and business outlook and new technology is well covered in other publications.

TABLE 14 Builders of Floating/Floated Platforms

Companies \ Application	Power Station	Desalin-ation	Paper-making Pulp	Water Re-injection	Gas Liquefaction and Storage	Site Hotel	Plywood	Luxury Hotel Leisure Centre	Concrete	Refinery	Ferti-lizers	TOTAL
I.H.I. (Japan)			1978									1
Kawasaki & Sasakura (Japan)		1978										1
Boelwerf (Belgium)										1962		1
Bath Iron (USA)	1974											1
Concrete Technology (USA)					1976							1
Mitsubishi (Japan)				1975		1975		1975		1977		4
Mitsui (Japan)								(1979)	1978			1+(1)
Tuymen (USSR)	1976(2) 1977(2) 1978(1)											5
Gotaverken (Sweden)						1978 (1979)					(1979 1980)	1+(2)
Marine Industries (Canada)	1971											1
Rossetti Marino (Italy)							1976					1
Tsuneishi (Japan)						1978						1
Valmet (Finland)						1978						1
Far East Livingston (Singapore)						(1979)						(1)
Unknown	1960											1
TOTAL	8	1	1	1	1	4+(2)	1	1 + (1)	1	2	(1)	21 +(4)

TABLE 15 Countries Using Floating/Floated Platforms

Country		Power Station	Desalin-ation	Paper-making Pulp	Water Re-injection	Gas Liquefaction and Storage	Site Hotel	Plywood	Luxury Hotel Leisure Centre	Concrete	Refinery	Ferti-lizers	TOTAL	
SOUTH AMERICA	Brazil	1974		1978							1977		3	4
	Venezuela	1960											1	
NORTH AMERICA	USA	1971											1	1
	Canada													
MIDDLE EAST	Saudi Arabia		1978				1978						2	4
	Abu Dhabi				1975		1975						2	
FAR EAST	Japan								1975	1978			2	5
	Indonesia					1976	(1979)						1+(1)	
	Pakistan											(1979 1980)	(1)	
NORTHERN EUROPE	North Sea						1978-(1979)						1+(1)	2
EASTERN EUROPE	USSR	1976(2) 1977(2) 1978(1)					1978						6	6
AFRICA	Cameroon							1976					1	3
	Libya										1962		1	
	Egypt								(1980?)				(1)	
TOTAL		8	1	1	1	1	4 +(2)	1	1 +(1)	1	2	(1)	25	

Offshore Port Facilities

The use of offshore port facilities has become increasingly attractive in the United States for three reasons:

- Dredging into the open ocean is required on the East and Gulf Coasts and on portions of the West Coast, to achieve the water depths necessary for very large petroleum tankers and some dry bulk carriers.

- Where deep water does approach the continent, coastlands are not suitable for the massive scale development required to handle solid and liquid bulks in multimillion-ton quantities.

- Increasing movements of dry and liquid bulk cargo have forced companies to use larger vessels to reduce the unit transportation cost of the commodity.

A substantial amount of research on the subject of deepwater ports has been conducted by the Maritime Administration, the U.S. Army Corps of Engineers, and the Department of Transportation. The future potential can be summarized as follows:

- East Coast--The eastern area of the United States is the leading consumer of petroleum in the United States and receives both crude and refined products by ship. Existing channel depths are limited to about 40 ft (12 mm), and economic and environmental problems make it unlikely that substantial improvements in channel depths will be possible. Thus the East Coast is a prime candidate for a deepwater port facility. A study by the U.S. Department of Transportation, concluded that "a deepwater port for crude petroleum imports is technically feasible and environmentally beneficial and under certain conditions, economically feasible."[2] It was not possible, however, to predict whether such a facility would be built because of the uncertainty of some of the economic factors.

- Gulf Coast--The largest concentration of refinery capacity in the United States is located on the Gulf Coast. As production of historic fields onshore and offshore in the Gulf Coast decreases, it becomes increasingly necessary to import crude oil as feedstocks for these refineries. A shallow shelf extends well into the Gulf, making it the most inaccessible coastal area for deep draft ships in the United States. This combination of circumstances has resulted in two offshore oil terminals being proposed for the Gulf: the LOOP development currently under way offshore of Louisiana and the Texas Deepwater Port, which is in the planning stage. The LOOP facility was licensed by the U.S. Department of Transportation (DOT) in August 1977, and was expected to be completed in late 1980 with a capacity of 1.4 million barrels a day. Second and third stages could be added, bringing total capacity to 3.4 million barrels a day by 1989 and total cost to $1.0 billion.[3]

• West Coast--The Straits of Juan de Fuca and Puget Sound provide the best protected deepwater accesss to any inhabited area of the adjoining 48 states. Proximity of deepwater to land at Los Angeles/Long Beach results in almost unlimited access to that harbor complex. Although oil-unloading projects in both areas have been controversial, it is unlikely that the situation will result in major offshore port development on the U.S. West Coast.

Maritime Industry Opportunities

To provide an order of magnitude estimate of the maritime industry opportunities from offshore port development, the committee examined the investment summary of the Texas Deepwater Port Authority project (formerly SEADOCK). A summary of the estimate is provided in Table 16. It can be seen that the marine facilities are estimated to cost $432 million based on a 1982 startup. Total maritime industry opportunities would be somewhat higher when it is considered that some of the "general costs" would constitute maritime industry work (primarily consulting and project management).

Assuming that two such facilities were constructed in the 1980-1990 time frame, the maritime industry opportunity would be in the range of $900 million.

Requirements for Realization of the Opportunity

1. R&D--The extensive history of successful offshore platform development by the oil and gas industry along with the history of the development and use of single-point moorings indicates there is little in the way of research needed before proceeding with these facilities.

2. Planning--Planning work has been completed for LOOP and Texas Deepwater Port with construction of LOOP well under way. A conditional license was issued by the DOT for the Texas project during August 1979. Planning studies have been carried out for an East Coast site, but substantial additional planning would be required before proceeding with site selection and design.[2]

3. Policy--the DOT (1978) study best summarizes the situation:

> "In light of all these uncertainties the development of a more positive Federal policy with respect to deep water ports must await the definition of a national energy policy."[2]

4. Commitments by Government and Industry--The development of deepwater oil ports requires a unique coincidence of interest and commitment by federal and state government and industry. Government must fully back the concept to assure that regulatory hurdles can be overcome and the permitting process completed on a timetable and at a

TABLE 16 Texas Deepwater Port Authority Investment Summary

MARINE FACILITIES	AMOUNT*
4 SPM's	$ 39,000,000
Quarters Platform	33,000,000
Pumping Platform	87,000,000
Pipelines:	
4-52 inch SPM;s	39,000,000
2-52 inch Trunklines	164,000,000
1-6 inch Fuel Line	11,000,000
Marine Support Facility	21,000,000
Supervisory Control and Communications	5,000,000
Equipment Mobilization, Risk Insurance, Other	33,000,000
TOTAL MARINE FACILITIES	$432,000,000
ONSHORE TERMINAL FACILITES	
Land	$ 2,000,000
Buildings, Sitework, Other	15,000,000
Tanks	172,000,000
Piping and Fittings	55,000,000
Pumping Equipment, Electrical, Meters & Auxiliaries	93,000,000
Supervisory Control and Communications	6,000,000
TOTAL ONSHORE TERMINAL FACILITIES	$343,000,000
GENERAL COSTS	
General TDPA Cost Prior to Operations	1,000,000
Permit Cost	1,000,000
Consultants, Technical Support, Quality Assurance	10,000,000
SEADOCK	11,000,000
Operations' Management	2,000,000
TOTAL GENERAL COSTS	$ 25,000,000
GRAND TOTAL CAPITAL EXPENDITURE	$800,000,000

*Based on 1982 Start-up and Completion of Facilities in 1983

Source: Texas Deepwater Port Authority.

cost consistent with industry and market needs. The transportation and ultimate disposition of the petroleum is in the hands of industry. Thus it must be fully committed to the project to assure financial feasibility.

External Factors Affecting Development

1. Unclear Jurisdictional Lines--While some of the uncertainties of these developments have been resolved by the Deepwater Ports Act (Public Law 93-627), and the LOOP and Texas proposals show that development is possible, the capability of a state or of an adjoining state to intercede or block such a development is unknown. The success of the President's proposal to expedite certain energy-related facilities has yet to be proven.

2. Ocean Transportation Development and Economics--Currently, oil transport rates are depressed because of an excessive supply of ships; this results in extensive oil lightering taking place because ships are available at low cost and can be delayed in their sailing schedules without severe penalties. Should this situation change, and the true cost of delays and excess vessel needs for lightering be borne by shippers, the economics of offshore ports would improve markedly. This situation is beyond the control of facility developers.

3. Onshore Port Facility Development--If onshore facilities and adequate channel depths are provided, the incentive to use the offshore port is diminished or lost. Recent proposals by the Port of Galveston to provide a 70-ft channel into the Gulf of Mexico have caused reassessment of the Texas plan. Similar types of opportunities exist on the East Coast, as do the opportunities for placement of offshore-type facilities in estuaries rather than at sea.

Market Levels under Various Assumptions

1. Minimum--Since the LOOP proposal is already under way, a maritime industry market of between $400 million and $500 million exists.

2. Most Likely--The committee believes that it is realistic to assume that one additional offshore port could be constructed in the 1980-1990 time frame with a maritime industry market of around $500 million.

3. Maximum--If problems surrounding the development of a deepwater port on the East Coast could be eliminated, another $400 million to $500 million market potential could exist.

The committee believes that it is unlikely that we will see offshore ports in the United States for dry bulk in the 1980-1990 time frame.

Ocean Disposal

There are three types of ocean disposal activities that have received extensive attention in recent years. The first of these is ocean disposal of dredged material by historic channel and harbor dredging activities, which in the United States is supervised by the U.S. Army Corps of Engineers. The second is the dumping of hazardous and nonhazardous wastes in the ocean--the major source of sewage sludge from metropolitan area treatment plants. The third is the use of incinerator vessels for hauling and burning certain wastes in the ocean to remove the undesirable side effects from inhabitated areas on land. Since all three of these ocean disposal activities have market potential for the maritime industry, they have been examined by the Committee.

Evaluation of Development--Past and Potential

Although somewhat out of date, a 1970 study by the Council on Environmental Quality analyzed and compared ocean dumping of dredge spoils and other waste materials.[4] Table 17 compares the orders of magnitude of these activities in the three ocean regions of the United States.

The Marine Protection, Research and Sanctuaries Act (Ocean Dumping Act) of 1972 (Public Law 92-532) and regulations published by the Environmental Protection Agency (EPA) in 1977 establish a comprehensive management system for the control of ocean dumping. An amendment to this act provides that the EPA:

> ". . . . shall end the dumping of sewage sludge into ocean waters. . . .by December 31, 1981."

Also, the International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter prohibits dumping certain wastes outright and establishes a permit system for a number of materials. The above mentioned U.S. laws essentially enable the United States to be in compliance with this agreement.

The use of coastal waters for waste disposal and use of shoreland for handling facilities represent a series of management problems that concern the coastal zone, water quality, international and national law, and transportation of the wastes to a coastal area and out to sea. Prohibitions against land and ocean dumping of hazardous industrial wastes require innovative ways to remove contaminating elements from the environment. One method is the use of incinerator ships to burn hazardous refuse at sea; other methods are dependent on the nature of the waste.

At present, there are two vessels functioning as incinerator ships; the VULCANUS, operated by a Dutch subsidiary of the Hansa Shipping Line

TABLE 17 Ocean Dumping: Types and Amounts, 1968 (In Tons)

Waste Type	Atlantic	Gulf	Pacific	Total	Percent of total
Dredge spoils	15,808,000	15,300,000	7,320,000	38,428,000	80
Industrial wastes	3,013,200	696,000	981,000	4,690,500	10
Sewage sludge	4,477,000	0	0	4,477,000	9
Construction and demolition debris	574,000	0	0	574,000	< 1
Solid waste	0	0	26,000	26,000	< 1
Explosives	15,200	0	0	15,200	< 1
Total	23,887,400	15,966,000	8,327,300	48,210,700	100

Source: Council on Environmental Quality

of Germany, and MATHIAS II, operated by Industrial Anlage of West Berlin.

A MarAd report concluded that ocean incineration of toxic chemical waste is economically and environmentally viable for U.S. flag ships.[5] The principal waste category to be incinerated would be chlorinated and unchlorinated liquid organic wastes. Quantities of environmentally acceptable and economically feasible waste range from 300,000 metric tons in 1977 to a projected 1,350,000 metric tons in 1989. The wastes are primarily from the organic and pesticide industries, with smaller quantities coming from the petroleum refining industry. Principal location of the wastes is on the U.S. Gulf Coast.

As shown in Table 17, the largest source of materials used in ocean dumping is dredging. While most dredged material is disposed of on land and in river and estuary areas, the availability of land and environmental regulations are forcing more dredged material to be hauled to the ocean for dumping. Historically, the U.S. Army Corps of Engineers (COE) has done most of this offshore dumping with their own hopper dredges.

Recent legislation has encouraged private industry to enter this business area, and two hopper dredges have been put into service by industry in recent years. The same legislation established a "minimum" fleet for the COE. Three vessels of that fleet are now under design or construction, and several more are in the planning stage.

Maritime Industry Opportunities from Ocean Disposal

The present laws and regulations will lead to a decline in ocean dumping of sewage and other wastes over the next decade. EPA reported that during 1978:

(a) Dumping of industrial wastes in the Gulf of Mexico declined by 99 percent and (b) the total tonnage of industrial wastes dumped in the Atlantic and the Gulf was 50 percent of the 1973 total. Maritime oportunities exist in the area of ocean incineration and disposal of dredged materials, which appear to be generally unaffected by ocean dumping regulations.[6]

The MarAd study indicates that demand and economic feasibility would support one ocean incinerator vessel in 1977, four in 1983, and five in 1989.[5] These are vessels of T-2 tanker size (16,000 DWT) with a capacity of 12,000 metric tons of waste.

In addition to the three dredges under construction, the COE estimates that five additional hopper dredges will be added to its fleet. Although timing of these additions is uncertain, the committee believes that it is reasonable to assume that five of these will be built in 1980-1990.

Excluding the private and COE dredges under contract, the committee estimates the marine industry opportunities from ocean disposal to be:

Minimum	$120,000,000
3 hopper dredges @ $40,000,000	
Reasonable	$245,000,000
5 hopper dredges @ $40,000,000	
1 ocean incinerator vessel @ $45,000,000	
Maximum	$415,000,000
7 hopper dredges @ $40,000,000	
3 ocean incinerator vessels @ $135,000,000	

Enforcement and Safety

The activities of law enforcement and safety on the sea predate the birth of this nation. The first formal recognition of maritime law enforcement in the United States dates to the chartering of the Revenue Cutter Service by Alexander Hamilton in 1790. This organization of ten cutters was established to enforce customs laws and facilitate maritime

commerce by suppressing piracy. Today maritime law enforcement is the responsibility of the Coast Guard, whose roots can be traced to the Revenue Cutter Service.

As this nation grew, its dependence on the sea as a medium for trade as well as a source of livelihood increased. Today this dependence is demonstrated by the diversity of businesses and institutions currently involved in or planning to become involved in ocean activities. As their numbers continue to grow, so do opportunities for conflict, spurred by a multitude of uses of the sea and its shoreline, each a potential conflict to another use. Examples of these uses are:

- An avenue for transporting cargo and people by ship
- A source of food
- A source of minerals, from the seabed, below it, and in seawater itself
- A source of renewable energy from temperature gradients, tides, waves, and biomass
- A medium for port operations and shipbuilding
- A medium for conducting research
- A depository for waste and dredged materials
- Human habitation
- Recreation and aesthetics
- National security
- Sites for industrial plant vessels and processing platforms
- An avenue for conducting antisocial and criminal activities

Although these uses have not all come into fruition, the potential for success is high. Consequently, competition for use of the sea, including nonuse, will increase, adding increased conflict and the resulting need for increased law and safety enforcement.

Maritime Industry Opportunities

As the diversity, density, and intensity of sea activities increase, the problems of public safety and law enforcement will increase even more steeply--perhaps exponentially. Table 18 shows the increase in enforcement activities by the U.S. Coast Guard. The enforcement of laws and safety requirements will necessitate an increase in the number of "platforms" from which such enforcement can take place. Those platforms will most likely take the form of seagoing vessels but will also include airplanes, helicopters, and lighter-than-air ships.

TABLE 18 General Law Enforcement Contraband Seizures by Fiscal Year
February 1, 1979

	1973-74	1975	1976&TQ	1977	1978	1979	Total
Vessels seized by Coast Guard	10	9	13	27	130	30	219
Vessels seized by other agencies with Coast Guard participation	4	1	8	20	26	6	65
Street value of contraband seized ($millions)	33.28	10.12	101.68	306	1194.5	503.67	2149.25

Source: U.S. Coast Guard

Requirements for Realization of the Opportunity

The design of enforcement vessels must be a joint venture between the user and the architect--the designer matching the user's definition of requirements with an appropriate platform. In this design R&D effort, however, particular attention should be given to the development of a coordinated mix of vessels to best meet law enforcement and safety requirements.

The enforcement of laws and safety regulations should receive the full commitment of the government. But this commitment must be tempered by the cooperation of the industries involved in order to ensure that law enforcement acts as a stimulant for economic growth and not as a hindrance. The maritime industry must continue to take an active part in developing those laws and safety regulations so that their industry's and the nation's interests are best served.

Market Levels under Various Assumptions

Table 19 represents the portion of the Coast Guard's 10-year capital investment plan that would most likely result in opportunities for the maritime industry. As one might suspect, this plan is the Coast Guard's "optimistic" capital investment schedule. The comparable fiscal year 1980 approved budget figure for similar capital expenditures is $109.6 million. Thus a "most likely" 10-year capital investment figure might fall somewhere between $1250 million and $2248.8 million.

The present active Coast Guard fleet consists of 246 cutters [ranging from 399-ft (120-m) polar icebreakers to 65-ft (20-m)-long

TABLE 19 U.S. Coast Guard Capital Investment Plan ($ Millions)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
WHEC a/											
Procurement						85.4	170.8				256.2
378' MMA b/	8.5	8.5	8.5	8.5	8.5	8.5	8.5				51.0
WMEC c/											
WHEC/WMEC Replacement								103.4	103.4		206.8
270' Procurement	206.8	155.1	155.1	155.1	155.1	155.1	155.1	51.7			1189.1
210' Replacement										5.0	5.0
ICEBREAKERS											
MACK/GACIER Renovation	1.7	10.2									11.9
WINDS Replacement d/	77.4		90.0								167.4
Type B Procurement							96.5			96.5	193
WYTM Replacement e/	13.7	41.1	41.1	41.1	13.7						150.7
BOATS											
30' SRB f/	2.1										2.1
55' ANB g/				5.5	5.5						11
63' ANB						3.2					3.2
TANB Replacement h/	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	1.0
	301.8	215	294.8	210.3	182.9	252.3	431	155.2	200	5.1	2248.4

a - High Endurance Cutter

b - Mid-Life Maintenance Availability

c - Medium Endurance Cutter

d - Arctic Icebreaker with 2' to 3' continuous ice-breaking capability

e - Ice Breaking Tug

f - Surf Rescue Boat

g - Aids-to-Navigation Boat

h - Trailerable Aids-to-Navigation Boat

Harbor Tugs] and 1577 boats [from general-purpose 16-ft outboards to aids-to-navigation boats 63 feet (19 m) long].

Marine Research

Prior to the 1960's, oceanographic research platforms tended to be vessels converted to this use. This was particularly true in the years following World War II when many surplus military hulls were available for conversion. These conversions represented very low investment costs for both the sponsor and operator of these vessels. It was not an entirely satisfactory situation, however, as vessels designed for military functions did not readily provide the optimum layout for these new missions. Recognizing this fact, the government in the late 1950's began design of a research vessel from the keel up. The first of this class, the ROBERT D. CONRAD, was laid down in 1961 and delivered in late 1962. CONRAD has eight sister ships in this first "class design" of research vessels. Three of these vessels are in the university research fleet, and the balance support government research programs, including one vessel each to New Zealand, Brazil, and Mexico.

While many other built-for-the-purpose vessels were supplied to the national oceanographic fleet during the 1960's, the CONRAD class is distinctive in that it represents the first U.S. experience with serial production of research vessels. Also, it should be noted that about 18 different shipyards participated in the construction of all post-World War II new vessel construction.

The 1960's also saw the advent of other types of marine research platforms as well as concurrent development of specialized shoreside support facilities for these platforms. Manned submersibles, fixed platforms, specialized buoys (such as the Monster Buoys), bottom crawlers (Scripps' RUM) unmanned submersibles, and special vessels (Scripps' FLIP) all added new tools to the oceanographer's capabilities. In varying degrees these new platforms involved technical and manufacturing support from the Navy and the ship construction industry. In addition, oceanography also took to the air through experimental use of aircraft and spacecraft. Of course, these airborne platforms did not involve the maritime industry but they did compete for resources that might have been allocated to the more traditional development of conventional research vessels.

One partial index to the rate of growth from the late 1950's to the present is given by contrasting the Federal Ocean Program Budget for fiscal year 1958, $38 million, to the budget for fiscal year 1981, about $1.1 billion. But as will be shown later, this rate of growth was not enjoyed by the <u>seagoing</u> marine-science sector. Furthermore, program areas used in the computation of the Federal Ocean Program changed over these years, and therefore this is only a very rough measure of real growth. In addition, inflation effects are factored into these numbers. Nevertheless, this spread offers a useful rough comparison.

Finally, the post-World War II years also saw the development of a commercial oceanographic fleet. Prior to this time the federal government, a handful of universities, and a few research stations operated a modest fleet of small research vessels. Commercial vessel services evolved to support applied offshore research in gas and oil, fisheries, and hard minerals. In recent years, commercial research work has been done in deepsea mining research in water depths as great as 3 miles. During the 1960's some rather large research fleets were operated by private enterprise (for example, Alpine Geophysical and Texas Instruments) to support Navy research requirements. While this practice is not quite so widespread at present, present trends indicate it may soon return because of Navy difficulties in constructing and supporting new research vessels.

The present situation in research platform operation, development, and management can best be summarized as nearly static. Since 1970 ten new vessels have entered the university research fleet, but total fleet size has shrunk from 35 to 25 vessels during this period. In this context, "university research fleet" means mainly government-funded (but not necessarily-owned) vessels.

The national (university and federally operated ships) oceanographic fleet presently in operation (1981) consists of 71 oceanographic research and survey vessels. The FY 1981 operational budget for this fleet is estimated to be $200 million. Table 20 indicates the makeup of this fleet. It should be noted that this listing is a pretty generous definition of "U.S. oceanographic research ships." Many of the vessels listed (e.g., icebreakers) have only marginal research capabilities. This problem will arise throughout this section: What is marine research? Of particular interest is the column, "Desired Retirement." This, of course, refers to the statistical life of a vessel. As a general principle one can say that the life of such ships is somewhere between 20 and 30 years.

With little effective forward planning being done at present to consider both replacements and additions to the national fleet, the 1980-1990 time period being considered in this study will be critical for this fleet. Table 20 shows that about 31 of the active 71 ships in the fleet (44 percent) will need replacement by 1990. There is no guarantee that replacement will occur. Improvements in vessel design and the productivity of onboard systems may mean that one or more ships may be replaced by a single ship of increased capability. A one-for-one replacement scheme may not be a universal truth. In addition those 12 vessels indicated for replacement through 1992 will require that planning and budgeting for their replacements will have to be done by 1990.

It should be noted here that some relative scale should be put on this federally supported fleet. For example, it is estimated that commercial research fleet and the academic fleet assets not supported by continuing federal appropriations may number another 150 vessels.

TABLE 20 Federally Funded U.S. Oceanographic Vessels and Related Capabilities (1981 Status)

Agency/Institution Operating Vessel	Vessel Length (feet)	Vessel Name*	Age of Vessel (in yrs.)	Condition	Desired Retirement
National Oceanographic and Atmospheric Administration (NOAA)	303	Oceanographer[1] (laid up)	12	Excellent	1990
	303	Discover[1]	15	Excellent	1990
	278	Researcher[1]	11	Excellent	1994
	292	Surveyor[1] (laid up)	18	Fair/Good	1984
	231	Fairweather[1]	13	Excellent	1992
	231	Rainier[1]	13	Excellent	1992
	215	Miller Freeman[4]	14	Excellent	1992
	231	Mt. Mitchell[1]	14	Excellent	1991
	163	Peirce[1]	18	Good	1986
	163	Whiting[1]	18	Good	1986
	175	McArthur[1]	15	Excellent	1989
	175	Davidson[1]	14	Excellent	1990
	170	Oregon II[4]	14	Excellent	1991
	187	Albatross II[4]	19	Good	1985
	164	Townsend Cromwell[4]	18	Good	1986
	171	David Starr Jordan[4]	16	Excellent	1987
	156	Delaware II[4]	13	Good	1991
	133	Ferrel	13	Excellent	1991
	90	Rude/Heck	15	Excellent	1987
	94	John N. Cobb[4]	31	Good	1980
	86	Murre II[4]	38	Poor	1980
University National Oceanographic Laboratory System (UNOLS)	245	Melville[3]	11	Good	1999
	245	Knorr[3]	12	Good	2000
	210	Atlantis II	18	Fair/Good	1993
	209	Thomas Washington	16	Fair/Good	1995
	209	Thompson	16	Fair/Good	1995
	208	Robert D. Conrad (laid up)	16	Poor/Fair	1983
	177	Oceanus	3	Excellent	2000
	177	Wecoma	5	Excellent	2001
	177	Endeavor	5	Excellent	2001
	172	Moana Wave[5]	8	Excellent	2003
	172	Gyre	8	Good/Excellent	2003
	170	Columbus Iselin[5]	10	Excellent	2002
	156	Kana Keoki[5]	14	Fair	1988
	133	Alpha Helix	16	Fair/Good	1988
	118	Eastward (laid up)	11	Fair/Good	1988
	110	Velero IV	33	Fair	1983
	106	Ridgely Warfield	14	Good	1993
	95	Ellen B. Scripps	16	Good	1992
	80	Cayuse	13	Good	1983
	80	Longhorn	11	Good	1990
	72	Blue Fin	9	Fair/Good	1985
	65	Hoh	38	Poor	1978
	65	Onar	27	Poor	1980
	64	Calanus	11	Excellent	1990
	170	New Horizon	3	Excellent	2008
	135	Cape Florida	1	Excellent	2011

* Capabilities which cannot be readily added to an existing ship:

1 Mapping and Charting
2 Polar Operation
3 Controlled Positioning
4 Fisheries Research
5 Van Capable

TABLE 20 Federally Funded U.S. Oceanographic Vessels and Related Capabilities (1981 Status) - (continued)

Agency/Institution Operating Vessel	Vessel Length (feet)	Vessel Name*	Age of Vessel (in yrs.)	Condition	Desired Retirement
U.S. Navy/Military Sealift Command (MSC)	246	Hayes	10	Excellent	1991
	455	Bowditch[1]	36	Poor	-
	455	Dutton[1]	36	Poor	1978
	563	Hess[1]	16	Excellent	1985
	285	Wyman[1]	10	Excellent	1996
	393	Harkness[1]	10	Excellent	1996
	393	Chauvenet[1]	11	Excellent	1996
	285	Bent[1]	16	Good	1992
	285	Kane[1]	15	Good	1992
	285	Wilkes[1]	10	Excellent	1996
	208	Bartlett	12	Good	1994
	208	De Steiguer	12	Good	1994
	208	Lynch	16	Good	1993
	262	Mizar[2,3]	24	Good	1983
	455	Kingsport	37	Fair	1986
	125	Acania	10	Good	1991
United States Coast Guard (USCG)**	108	Evergreen[2]	38	Fair	1985
	269	Northwind[2]	36	Good	1987
	269	Westwind[2]	36	Good	1985
	309	Glacier[2]	27	Good	1985
	399	Polar Star[2]	5	Excellent	2000
	399	Polar Sea[2]	5	Excellent	2000
Dept. of Interior U.S. Geological Survey	180	Sea Sounder	37	Good	-
	205	Samuel Lee[1]	13	Excellent	1993
Environmental Protection Agency	165	*Antelope*	4	Excellent	1998
National Science Foundation	400	Glomar Challenger	13	Good	1988
	125	Hero	13	Fair	1988

* Capabilities which cannot be readily added to an existing ship:

1 Mapping and Charting
2 Polar Operation
3 Controlled Positioning
4 Fisheries Research
5 Van Capable

** All USCG vessels except the Evergreen are icebreakers which are used by other Federal agencies when available for polar related research.

But many of these vessels are in the 40 to 100-foot length range, so precise counting is difficult. By comparison, the Soviet research fleet numbers some 260 vessels of all types, 70 of them over 1000-ton displacement. The United States has only a handful of vessels of this size.

The principal difficulty in supporting an expanded national research fleet lies in decreased support (in constant dollars) for marine sciences since the beginning of the 1970's. Even though federal support has increased to the $1.1 billion level, the recent real growth after inflation and other accelerated costs is near zero. It should be noted that of this figure of $1.1 billion the amount directly put into seagoing marine research is on the order of only 30 percent. While some studies maintain that U.S. investment in marine sciences has in fact grown during the period 1968-1981, the net impact has been minimal. Some of this can be attributed to the creation of new federal agencies (e.g., NOAA, EPA, and DOE) that have legitimate ocean-related activities but the administrative overhead of these organizations' ocean programs is charged against the federal ocean program count. There has not been a commensurate increase in programmatic activity at the <u>research program</u> level. This is not to say that new agencies are not important. It should be recognized, however, that their overhead costs are charged against the federal ocean program and may not be reflective of true growth of seagoing marine science.

In addition, inflation in marine operations increased at a rate far greater than overall inflation within the United States. For example, fuel costs in 1973 represented only 6 percent of the ship operating budget. In 1981, we estimate that fuel will represent 22 percent of the operating budget. This coupled with rapidly escalating labor costs means that the fixed dollars fed into the national research budget result in less seagoing science per unit of cost.

Since research vessels represent a key element in marine research, any slowing or decrease in national support will be reflected in a reduction of these assets. The problem is compounded in that the acquisition of new research vessel "assets" is now a fairly long-lead-time process. Five years is reasonable from federal agency budget planning to final delivery of the vessel to the user.

At present, only two new federally funded oceanographic vessels are in the pipeline. These 124-ft coastal research sister ships will go to Duke University and the University of Miami. They are being funded by the National Science Foundation (NSF) and will be in service by 1981.

Future

Many experts concerned with long-term management of marine sciences believe that there will be an eventual turnaround of the present depressed funding of the national oceanographic fleet. In addition,

the general resolution of restrictive environmental concerns on development of gas and oil on the U.S. continental shelf and margins will lead to increased activity for the commercial research fleet (in geophysical surveys, fine grain mapping, and environmental monitoring, for example). The advent of ocean mining in the late 1980's will also bring more research work for the commercial fleet operators. Once commercial exploitation is under way, there will be added research activity in the environmental monitoring of these activities.

The fundamental precondition is, of course, a renewal of expanding federal support for the nation's ocean research program. This is what happened in the late 1950's and through the end of the 1960's. But before any real new initiative can be expected, there has to be some establishment of a more coherent, integrated national ocean policy. Such a policy will put the role and contribution of marine research in the overall proper perspective with respect to national goals for uses of oceanspace.

A future concern about the role of scientific research is also found in the resolution of the present United Nations Law-of-the-Sea negotiations. The negotiations indicate that freedom of marine scientific research once enjoyed at sea will soon be greatly restricted. This does not mean that no research will be done, but it does signal some fundamental changes in how it can be accomplished. There will be more future research involvement of the coastal states adjacent to the research site. This involvement may even carry as far as providing special handling and intrepretation of the data for the use of that coastal state. This would apply even if the data were taken for some other scientific purpose. The cost of doing marine research in this environment will surely rise. But it could also establish increased oceanographic activity on a worldwide basis. This situation could provide added demand for ship assets, especially in developing countries.

Maritime Industry Opportunities

If one considers a "perfect world situation" of a one-for-one replacement of those vessels indicated in Table 20, using an annual inflation rate averaging 6 percent (a very conservative rate but simply for reference) for the 1980-1990 time period, we can establish a ship construction program of 31 vessels at a mean cost of $8 million (equipped). This could represent a program total of $250 million over this decade. This may sound like a large figure, but one only has to consider the costs of major vessels for the Navy or the merchant fleet to see that this figure is rather small (and perhaps too conservative). With modern attack nuclear submarines costing $300 million to $400 million and LNG ships costing $150 million to $200 million, a $250 million research ship program is rather modest. This will all be handled through medium-sized shipyards. Major civilian yards and government shipyards largely will not be involved in this replacement program.

While these 31 ships will represent a range of sizes, it is likely that they will be mostly in the 100-200-foot- length category. It is unlikely that these new vessels will be of the same basic designs as the ships they replace. Such events as the fuel shortage, increased manning costs, new marine engineering advances, and high-technology instrumentation systems, will contribute to making these new vessels more cost effective for the operator and more productive for the researcher.

A reasonable assumption will be that the national ocean program might grow by a total of 10 percent above inflation during this same decade. If we assume that this would call for a similar increase in ship capacity, we can add about eight new ships and another $64 million to the ship construction budget.

While these rough calculations deal with the government-sponsored research fleet, there is every reason to believe that the commercial research fleet will enjoy a certain amount of entrainment through the expanded government programs. It may be that the commercial fleet will have to be used to meet extra demand generated by the increased government research program, since the government ship construction program will probably lag behind the need for seagoing assets. A related scenario would be one in which the government deliberately encouraged the private sector to build and lease these ships rather than (the government) acting directly in this role. This action would stimulate both shipbuilding and operations (i.e., seagoing labor) sectors of the maritime industry.

There are already some considerations within the government to set up better central management authorities to manage the government-sponsored research fleet. A 1978 U.S. General Accounting Office (GAO) report recommended that Congress designate a single manager for government-wide civilian agency oceanographic vessel operations.[7] This is not a popular view among many who are directly involved in research vessel operations, but it does indicate high-level attention to a serious problem. Further, the GAO report prefaces this recommendation with the statement, "Until a comprehensive national ocean policy is established, we recommend. . .". Clearly a national ocean policy will be the key to the development and expansion of our national research fleet. Only in this way can front-end research be tied into effective end-point uses of the sea.

If the ship replacement and new additions programs are done through a centralized, planned effort, there may be considerable market opportunities for ships sales overseas to developing coastal states. By building two to three class ships, production economies could result that would make these vessels competitive in overseas markets. In the area of high-technology ship construction (i.e., the LNG vessels) the United States is still competitive. This may be the case with the new research vessels _if_ the program is properly designed. Since 86 percent of the coastal nations in the world are third world nations, the market is there.

Requirements for Realization of Opportunity

Research and Development--Better coordination is required between ship sponsors and the user community (the researchers) to ensure that design feedback and requirements are established. More attention needs to be given to the application of advanced ship technologies to research vessel design (i.e., SWATH, hydrofoils, and surface effect). Designs that offer great stability and efficiency in small vessels will be particularly important.

Policy and Planning--A national ocean policy is an important precondition for planning replacements and additions to the national ocean research fleet. Knowledge of the marine environment and its resource potential precedes any effective national program of resource exploitation. Specific planning for the vessels themselves must involve the users as well as the sponsors. It must be clearly understood that creation of seagoing research assets is a long lead time process which takes years to accomplish.

Commitments by Government and Industry--Government must commit to orderly exploration of the oceans in support of national ocean development. It must assure allocation of the necessary policies and resources to do this. In addition, government should establish initiatives and incentives for greater industry involvement. Industry must be prepared to make the necessary capital investments to support increased industrial research in the oceans.

External Factors Affecting Development

The present Law-of-the-Sea negotiations will affect U.S. marine research by making access to waters within 200 (or perhaps 350) miles of a foreign coastline more difficult. However, this may also generate new business opportunities in assisting the developing coastal states to assess and exploit their coastal resources. U.S.-developed assistance programs in this area could provide tie-in contract work for our research vessels as well as potential sales of new vessels and equipment.

The uncertainties of the world fuel situation and operating personnel costs have provided budgetary problems that are increasing at a rate considerably more than the average rate of inflation. With relatively fixed budgets for the U.S. research fleet, the result is reduction of time spent at sea and the removal of some ships from the fleet. Improved ship design and advanced marine engineering technologies may provide some improvement in manning and fuel consumption efficiencies, but it is clear that the future federal research fleet must be funded at a more realistic rate. The commercial fleet will only survive if it can pass along the increased costs to its customers.

Oceanography is "big" science, involving the use of sophisticated, high-capital-cost facilities. Not every federal agency or nongovernmental research institution can (or should) afford the luxury of owning all the assets that they might need. This "need to own" has been evident in the past but is unaffordable in the future. Better coordination and management are required for federal fleet assets. Recent Congressional hearings suggest that this will be done to ensure maximum efficiency of the existing fleet before consideration is given to replacements and additions.

It is not clear whether the government will be able to develop a national ocean policy in the near future (2-4 years). This is largely a matter of initiative on the part of the President.

There is now serious concern about the erosion of the U.S. technology base. The advent of new technological ideas (i.e., transistors, microelectronics) has slowed greatly, and foreign competition is a serious threat. If the U.S. Government is able to turn this trend around there should be a beneficial entrainment of the marine science and engineering areas. This would stimulate and support more seagoing research.

Market Levels under Various Assumptions

Minimum--In this case there would be no significant ship replacements and no new additions to fleet capacity (over and above required replacements). New ship funds would be utilized for life extension and modification programs for existing vessels. The estimate would be 27 new vessels in this time period. This is, in fact, the estimated number of ship replacements called for by the academic community (through the NSF's University National Oceanographic Laboratory System, UNOLS) and by the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce. Between these two organizations there is a demand for some 27 new vessels in the next 10 years. Replacements for the Navy and other federal agenices are not included in these numbers. Limited overseas sales and new commercial research fleet additions might add another 6-8 vessels. Total value in new ship construction would be on the order of $270 million. This includes outfitting with scientific equipment. This figure includes only vessels. Other platforms, such as submersibles, aircraft, and spacecraft, are excluded.

Maximum--A national ocean policy provides the planning framework for expanded national programs in the oceans. Therefore, a large increase in marine research is initiated as a result of increased national ocean activity. About 40 of the 71 ships currently in the federally supported research fleet will be replaced. In addition, new units will be constructed to expand fleet capabilities. It is estimated that the net fleet increase would be 10 percent or 8 ships. The value of 48 new construction vessels would be in the order of $385

million. Increased federal ocean activity would provide growth opportunities for the commercial research fleet as well as overseas sales of research vessels. In these areas, replacements and new additions are estimated to be in the order of 30 vessels, for a value of $240 million. Thus the total new construction for the maximum case would provide about $625 million of ship construction work. As noted earlier in this section, almost all of this work will be placed with medium-sized and small shipyards. Little will be done either in Navy shipyards or the major shipyards.

Most Likely--A modest effort will develop as the result of a modest national ocean policy formulation. The government will emphasize the tie between maritime capability and national security. The marine research program will be expanded (5 percent above inflation), but considerable effort will go into cost reductions through centralized management, reduction of overlap, and better program coordination. With respect to the federally supported research fleet, there would be some consolidation of assets such that not so many replacement vessels would be needed as indicated under the maximum case. In addition, new systems such as submersibles, aircraft and satellites will do some of the work previously done by ships. There would be, however, new additions to the fleet, which would provide added capabilities not present in the existing fleet. It is estimated that the fleet would grow by about a net of 10 percent, a final fleet size of about 80 ships. Estimating that about 30 vessels will be replaced and 8 new additions constructed for a total of 38 new vessels. This will have a value of $304 million. Commercial research fleet additions and overseas sales will add another 20 vessels for a value of $160 million. Thus the total value for the most likely case is $464 million.

Summary

While many assumptions have been made in this section with respect to numbers of vessels in the fleet, their desired replacement times, the growth of federal funding support during the decade, and unit ship costs for this period; this analysis is still useful as a baseline reference. Due to budget changes in particular, some of the numbers for ship operations and procurement may vary. Even assuming large scale changes in some of the assumptions used, one can still get an idea of the general order of magnitude of the maritime industry potential in the area of marine research.

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CHAPTER 7
FINDINGS AND CONCLUSIONS

About 20 years ago our nation began a period of heightened and broadened interest in the ocean and its usefulness to the people. The traditional ocean uses, namely, for transportation, as a medium of protection of our borders and as a source of food, have always been recognized, but this new interest led to an increased awareness of other ocean resources that are or could become of importance to the United States. In January 1969, a report was issued by the Stratton Commission, which was appointed by the President to study the ocean and its promise.[1] The Stratton Commission Report was optimistic with respect to the relatively near term exploitation of additional ocean resources.

On examining some of these same areas of ocean resources, this committee finds that, indeed, the resources are there and the scientific and exploratory work to confirm this conclusion has been done to a considerable extent. The technological base on which the means of recovery and use of the resources can be built and deployed has been developed. More scientific work and technological development are needed, but in the committee's opinion, the true factors pacing the effort to bring many of the resources into use and to achieve the many benefits are of an economic, legal, and public-policy nature. The significance of the several resource areas is, therefore, affected by these same pacing factors and is reflected in maritime industry requirements that have been or will be developed for ships, new technology, and a more-varied capability.

Not unexpectedly, the requirements that ocean-resource development places on the maritime industry do not show sharp differences from one resource to the next. From the viewpoint of the maritime industry, the opportunities for growth and diversification lie mostly along lines already recognized and being followed, in general, as demands dictate. While this is, indeed, the dominant trend, other opportunities do exist, and new requirements are evident.

To summarize the foregoing and to provide a structure for reviewing the results of the committee's study, the following general conclusions can be stated as they apply with more or less validity to each of the

areas of resource studied. The rest of this chapter will look at each general conclusion in the light of the several resources that were studied.

General Conclusions

1. Ocean resources are known and proven by sufficient scientific research and exploratory results to permit general assessment of the recovery value and cost. The extent to which this is true varies among the resources considered, and more such exploratory and development work is still needed in some areas to complete the picture.

2. The basic technology necessary to exploit ocean resources is not today a limiting factor; necessary specialized equipment has been brought to the prototype stage, and testing in most cases is under way or complete.

3. The shipbuilding capabilities, manpower, and resources are readily available for application to the task of winning resources from the ocean.

4. The controlling influences on ocean resource development are, today, largely those of economics, national and international law, and public policy. In many cases, these elements are interrelated, and the effect on resource recovery progress is the result of these influences.

5. Economics will, in the end, be the most important positive driving force in resource recovery. Other considerations such as laws, regulations, and public policy will be felt largely in the degree to which those elements slow or inhibit the growth of the resource extraction industries.

6. Market projections indicate that opportunities exist for the maritime industry from activity in most of the areas of resource development, a number of which are known and recognized already. New opportunities have been identified in the directions of immediate promise in resource development. Although these are individually somewhat limited in scope, the overall picture is one of a substantial opportunity for the industry.

Availability of Resources

The list of ocean resources that the committee found to be of practical interest in the time frame used in the study (1980-1990) contains no recent discoveries; all have been known for decades to exist in the ocean. For many of them, oil and gas and oceanfloor nodules being examples, interest in exploration and measurement of the extent and available amounts of the resource waited until growing need had sufficiently pushed forward the technology for recovery.

In all the areas of ocean resources that the committee studied and reported on in the foregoing chapters, the extent, quality, and availability of the resource had already been measured sufficiently to assure the existence of significant quantities representing a real opportunity for recovery and use. However, not all areas of the ocean have been explored and resources measured as thoroughly as those reported. Although the existence of nodules has been known since the 1870's, data derived from manganese nodule exploration and sampling for commercial development is recent and has much further to go to provide the needed solid base of data for funding a large-scale operation. On the other hand, the body of information on gross ocean thermal contours, which is fundamental to the study of the practicality of ocean thermal energy, is available. Detailed information is being developed.

Conclusions relative to availability of resources are summarized in Table 21.

TABLE 21 Summary of Conclusions Relative to Availability of Resources

Resource	Conclusions
Oil/Gas	1. U.S. production has peaked already. 2. Foreign imports will peak in the 1980's. 3. Increasing pressure to expand doemstic sources of oil and gas will occur. 4. Primary increases will be in new and rework areas of continental shelf, including Alaska and all marine areas.
Energy	1. Ocean thermal energy only renewable resource of significant availability in the 1980s's. 2. Ocean thermal energy availability in southern U.S. waters could equal 8-23 percent of current U.S. consumption. 3. Of immediate interest is the fact that U.S. island areas (e.g., Hawaii) lie on belt of maximum availability of ocean thermal energy.
Living resources	1. One-fifth of world's known exploitable fisheries lie within U.S. 200-mile limit.
Ocean mining	1. Manganese nodules most significant resource potential. 2. Pacific Ocean nodule beds able to sustain commercial-scale operation through next century based on preliminary exploration. 3. True potential of deep-seabed mining needs further exploration for full assessment.

The State of Existing Technology and Industrial Base

As the committee began its study of the ocean resource areas and the potential opportunities that the maritime industry will have in their development, it seemed that improvement of existing technology and broadening the existing industrial base would be the important challenge to the industry. True, the present state of recovery technology of the various resources varies; in some cases (e.g., oil and gas) most of the basic technology is there ready for use. In other cases (e.g., ocean mining) the pilot-plant equipment is being tested, but scale-up to commercial operating size is yet to be done. However, for the resources that became the focus of the study this turned out to be a less-significant factor leading to development than the constraints of economics, law, and public policy. However, when the screening process used by the committee to focus on opportunities in the next ten years is taken into account, it does not seem surprising that an existing and moderately well-developed technological base would be a necessity for any resource to show promise in that time frame.

Another plus factor for the technology is that the maritime industry's industrial base of shipyards and suppliers is particularly ready in the current period to take on efforts, since the current and prospective workload is not large. A notable example of this basic readiness on the part of the maritime industry can be found in the area of oil drill rigs and ships. As the offshore drilling business increased, the shipbuilders and heavy construction industries were able to move rapidly in this field and meet demands as they came.

Manpower, also, is available for the development of the new resources, although a degree of training in new fields and specific equipment will be necessary. The oil and gas industry has shown that this needed training can be achieved and the rapid turnover that characterizes operations under unusual and difficult circumstances can be handled.

Conclusions relative to the state of existing technology are summarized in Table 22.

TABLE 22 Summary of Conclusions Relative to the Conclusions of Existing Technology

Resource		Conclusions
Oil/Gas	1.	Ocean drilling to 600 ft is well proven and represents the bulk of operations in the 1980's.
	2.	Deepwater drilling technology will be ready when need occurs.

TABLE 22 Summary of Conclusions Relative to the Conclusions of Existing Technology (continued)

Resource	Conclusions
Oil and Gas	3. Arctic drilling, a significant opportunity, needs further technology development--regular operations will start in the 1980's. U.S. Government should provide leadership in sponsoring R&D work on ice technology.
Energy	1. Pilot-plant ocean thermal energy plant design and component testing indicates that all elements can be provided with existing basic technology. Adapting that technology to this system is still a challenge. 2. Major design, development, and testing is required for coldwater pipe, platform mooring, and electrical transmission. 3. Full-scale tests needed to prove out whole system.
Living resources	1. Technology and facilities exist to produce the larger, more efficient, and technically advanced fishing vessels.
Mining	1. Oceanfloor mining has proven feasible in tests. 2. Scale-up of operations to commercial size is needed to prove commercial reliability. Vessel systems increase in size to 100,000-150,000 DWT size is needed. Also dynamic positioning requires scale-up. 3. Transfer at sea of large volumes of slurry is a problem requiring further significant development. 4. Processing systems for nodules are still in pre-pilot-plant stage.
Ocean space	1. Technology exists for offshore port or platform development. 2. Advanced vessel design for oceanographic and other special uses is largely available. Demands by users will generate improved designs.

The Market for Ocean Resources

The economic potential driving the process of ocean-resource development has been judged by the committee as being one of the most important factors. "Is there a market for the resource in question?" was asked in each case. The economic forces now at work or anticipated in the next ten years were the principal considerations if a significant opportunity for the maritime industry is to develop. Government sponsorship of the developments was not dominant and, in some areas, virtually nonexistent.

Market, or economic, forces do not, however, operate in a vacuum. The presence (or absence) of government policy in the form of law, regulation, tax structure, and R&D support, affects very significantly the development of ocean resources. It is this interaction of law and policy with the economic potential of the resources considered that the committee found most important in the final assessment of opportunities for the maritime industry.

Conclusions relative to the market for ocean resources are summarized in Table 23.

TABLE 23 Summary of Conclusions Relative to the Market for Ocean Resources

Resource		Conclusions
Oil/Gas	1.	Economic forces will exert great pressure for development of the resources, both through new discovery and rework of old fields.
Energy	1.	A significant economic incentive exists for use of ocean thermal energy, particularly in U.S. island market.
	2.	A significant fraction (8-23 percent) of continental U.S., and all of U.S. island, baseload electrical needs could be met by ocean thermal energy in the 21st century--if pilot plant and subsequent full-scale test plants are successful.
Living resources	1.	Growth of U.S. demand for fisheries products is exceeding population growth.
	2.	Retail expenditures grew from $1.7 billion to $7.4 billion between 1960 and 1974.
	3.	Fishing imports are generally more expensive than U.S. fisheries products.

TABLE 23 Summary of Conclusions Relative to the Market for Ocean Resources (continued)

Resource	Conclusions
Mining	1. Imports of metals, especially those sensitive to defense needs, come from uncertain sources of supply. 2. The nickel, colbalt, copper, manganese, and molybdenum from deep-sea nodules are the same metals that will be in demand because of a major effort to develop alternative energy sources. 3. Nickel from deep-sea nodules is already coming close to the cost of nickel from a typical find in a remote, less-developed country.
Ocean space	1. Offshore ports are becoming more economically attractive in Gulf and East Coast areas, as land areas become scarce. 2. An assumption of one, perhaps two, large offshore port developments in the 1980-1990 time frame might be reasonable. Cost would be in the range of $500-million to $900 million. 3. Ocean disposal opportunities in the next decade range from 3 to 7 hopper dredges at about $40 million each and, perhaps, one ocean incinerator vessel. 4. As the diversity and intensity of sea activities increase, the enforcement of laws and safety requirements will require more vehicles for the purpose; seagoing vessels will form the majority of these vessels. 5. Ocean-research vessels now in service, if replaced on a one-for-one basis, will represent a replacement program of perhaps 31 ships and $250 million over the decade. 6. The growth of the U.S. national ocean program may cause as much as a 10 percent increase in the number of high-technology research vessels; but an even greater potential market lies in the many emerging nations that comprise 86 percent of the world's coastal nations.

The Constraints Affecting Ocean Resource Development

Although the committee found that the ocean resources being considered in the study had definite market potential within the time period studied, it was also apparent that important constraints limiting the opportunities are present. Those constraints lie to a great degree in the political and public-policy areas, both national and international, and also in the laws and regulations that reflect those policies. None of the resource areas studied are free of these influences, and few of them can actually achieve the potential of which they are capable without a favorable climate in the legal and public policy fields.

Examples abound. The economic effect of the current debate on energy policy is obvious. So too is the importance of resolving the growing confrontation with environmental groups seeking to limit offshore oil and gas activities.

Deep-ocean seabed mining may encounter future environmental clashes. But even before that happens a resolution of the international concerns over the law of the sea will be necessary to make full-scale development of this resource attractive to the investment world.

In the case of almost every ocean resource studied, it has been seen that cooperative R&D efforts by both government and industry are one of the keys to development of the resource. Ice technology, so important to future offshore oil and gas activity, is an example. Another important resource that is dependent on the exercise of positive public policy toward R&D is the ocean thermal-energy program. These considerations lead back again to the need for a consistent overall ocean policy in which R&D programs and goals would be defined.

Another among the constraints to ocean resource development that the committee noted was the competition for space and priority of use among some of the ocean resources themselves. The ocean space is large, but the areas needed for undisturbed operation of, say, the fishing industry, are also large. Conflicts have been seen already between fishing interests and oil-drilling rigs. Each of the resource systems requires an onshore connection and support--each such requirement provides the scene for competition for ocean space and for clashes with coastal zone policy and planing.

A summary of conclusions relative to constraints affecting ocean resource development is given in Table 24.

TABLE 24 Summary of Conclusions Relative to the Constraints Affecting Ocean Resource Development

Resource	Conclusions
Oil/Gas	1. Environmental concerns, and the laws and regulations resulting from these concerns, are important constraints. 2. An effective means of containing oil spills, and controlling the contamination resulting from offshore oil and gas operations, is lacking. This fact hampers operations offshore. 3. Ice is a major constraint in the move of the offshore oil and gas industry to promising Arctic areas. 4. Trained manpower becomes a constraint as the pace of offshore operations increases. Training schools sponsored and supported by public policy will be needed to overcome this costly constraint. 5. For healthy growth, the offshore oil and gas industry must establish credibility with the public. This is best achieved through a favorable public-policy climate, the establishment of a national energy policy, and the dissemination of reliable factual information on the subject.
Energy	1. The legal status of the OTEC plant, whether cable-connected or free-floating, has not been established. 2. National regulatory laws concerning liability, safety, and the environment, leave serious areas of ambiguity and uncertainty affecting the development of this resource. International law is equally of concern. An established body of law and standards relating to the regulation of OTEC platforms is needed. 3. Large capital investment needed for full-size OTEC plants will come only after successful pilot-plant performance and economic viability have been demonstrated. Active participation by the federal government in pilot demonstrations will be needed to motivate private industry to make the necessary investment.

TABLE 24 Summary of Conclusions Relative to the Constraints Affecting Ocean Resource Development (continued)

Resource	Conclusions
Living resources	1. The lack of efficient fishing vessels of larger size and advanced design has been the single largest constraint in the U.S. fishing industry. Recent federal policies and actions may lead to improvement and eventual removal of this constraint. 2. U.S. consumer demand for certain species of fish, and the neglect of others, results in underutilization of millions of metric tons of potential harvest. 3. Conflicts are created by the many environmental laws, some of which have unintended, but clearly detrimental, effects on the fishing industry.
Mining	1. Pilot processing-plant operation will need a large quantity of nodules (10,000 to 20,000 tons) to prove out the system. The total gathered to date by all programs is approximately 2,000 tons--a serious constraint is indicated for the gathering of additional necessary nodules with available means. 2. Serious environmental impacts will exist. These have only begun to be studied. 3. The most critical constraint is the absence of agreement on an international Law of the Sea as it relates to the industry. This could delay realization of the deep-seabed mining resource beyond the time frame of this study.
Ocean space	1. The lack of a coherent national energy policy will adversely affect the development of the positive federal policy needed for deepwater port development. 2. Ocean disposal is facing a decline in future years because of present environmental law and regulations. 3. Construction of vessels for U.S. law enforcement and safety programs, will depend on government policy with regard to regulation enforcement. 4. The present static program of federal funding and support of ocean research will, if unchanged, hamper the renewal and expansion of the U.S. ocean-research fleet.

Opportunities for the Maritime Industry from Development of Ocean Resources

The overall conclusion that the committee has reached relative to the opportunities for the maritime industry in the realization of the potential of the ocean resources is that the opportunities are surely there. The economic potential is certainly great, but accurate prediction has been found to be quite difficult. This is because large uncertainties exist in each area. In oil and gas, for instance, the economic force for development is unquestioned but the concern for public policy and availability of the resource are great. Similarly, the ocean mining resource field is in a virtual hiatus awaiting the outcome of international and national legal questions. If those were settled, it still remains to prove the technical systems, as well as to solve the financing and environmental questions.

These questions and many others like them have been discussed in this report under the heading of constraints. The resource areas that the committee studied in detail were considered to have proven availability and excellent market potential. The matter of the constraints to the realization of the potential is therefore all important in assessment of opportunity. The committee was required to study these constraints and to make some estimates as to their present importance and future trends in order to reach conclusions as to the opportunities in each resource area.

The variability of future events lead, of course, to a fairly wide band of reasonable estimates for the resource opportunities. In many cases, the upper and lower limits are stated and a "most-likely" central estimate is given in the individual chapters. It is this "most-likely" case that is summarized in Table 25.

TABLE 25 Summary of Conclusion Relative to the Opportunities for the Maritime Industry from Development of Ocean Resources

Resource	Conclusions
Oil/Gas	1. Fabrication of all types of drilling rigs for offshore use is the strongest market potential. A forecast of about 35 rigs per year at about $700 million each year for the next 10 to 20 years is reasonable.
	2. As the economics of the petroleum industry develops, deepwater drilling for petroleum will increase in importance. The maritime industry must keep abreast of the developments to be prepared for this future opportunity.

TABLE 25 Summary of Conclusion Relative to the Opportunities for the Maritime Industry from Development of Ocean Resources (continued)

Resource		Conclusions
Oil/Gas	3.	Support/service vehicle construction will be an important opportunity--250 to 350 vessels per year at $500 million to $1 billion per year.
	4.	Arctic petroleum activities will require a significant increase in Arctic research and development--$25 million to $50 million over the next 5 to 8 years.
	5.	Small submarines for deepwater operations will be in growing demand in the next decade, and the R&D on these will be accelerated. An annual growth of 20 to 50% in the total investment in untethered submersibles can be expected.
	6.	Oil-polluion containment and recovery systems offer opportunities for much-needed innovation. Federal and oil industry support for R&D is particularly needed here.
	7.	The offshore platforms, after petroleum production ceases, will present an opportunity for development of alternative uses instead of costly removal. Government and industry should jointly support R&D toward this end.
Energy	1.	Thermal energy of the ocean is the only source of ocean energy offering an opportunity to the maritime industry in the next decade.
	2.	The major focus of maritime opportunities will be in the design, construction, and operation of two or three pilot OTEC plants.
	3.	Major plant production will depend on tests of the pilot plants; given successful tests a major program could start near the end of the 1980's and reach full pace in the 1990's.
	4.	The pace of OTEC energy development rests importantly on decisions as to the level of R&D efforts of government and industry and in resolution of other legal and regulatory questions affecting production and operation of commercial OTEC plants.

TABLE 25 Summary of Conclusion Relative to the Opportunities for the Maritime Industry from Development of Ocean Resources (continued)

Resource		Conclusions
Living resources	1.	With the passage of the Fisheries Conservation and Management Act of 1976, the balance has begun to shift from the previous situation of foreign exploitation of U.S. fisheries to greater fish supply to the U.S. fisherman and greater stock stability.
	2.	U.S. fisheries suffer from the U.S. consumer's demand for certain species and the rejection of others. Efforts by the government to promote under-utilized species, if continued and strengthened, will increase the opportunities in fisheries.
	3.	Increased demand for fish will provide the impetus, and favorable government policies for financing aids to the construction of significantly improved fishing vessels will encourage the impressive growth that the industry is expecting.
Mining	1.	Deep-seabed mining is the principal source of new opportunities for the maritime industry in this area.
	2.	Seabed exploration for nodules will increase in the immediate future because limited work has yet been performed and the system is sensitive to the certainty of its available supply of nodules. In the next decade, $10 million to $15 million will be spent each year by the present consortia working in the field.
	3.	Marine construction and engineering services in support of ocean mining systems is highly dependent on legal, political, and economic factors. Assuming favorable resolution of these questions, the market for mining vessels and transports could amount to a total of $1 billion to $2 billion in the next ten years.
	4.	Included in the opportunity for marine construction activity of the last paragraph is the requirement and opportunity for the industry to develop a large number of specialty areas in shiphandling, navigation, transfer-at-sea, and mining operations. R&D in these areas should stay at $10 million to $20 million annually during the decade.

TABLE 25 Summary of Conclusion Relative to the Opportunities for the Maritime Industry from Development of Ocean Resources (continued)

Resource	Conclusions
Ocean space	1. A most likely level of activity in the construction of deepwater ports is that one additional facility of this nature will be built in the next decade at a cost of $500 million. 2. If the political and economic uncertainties surrounding this area can be eliminated, a second such port is also a possibility in the 1980's. 3. A reasonable assessment of opportunity for the maritime industry in ocean disposal is that five hopper dredges and one ocean incinerator vessel at a total cost of over $200 million will be built in the next decade. 4. Vessel construction for Coast Guard use in enforcement and safety purposes will most likely increase from a current expenditure of $110 million per year to a total expenditure of $1250 million to $2250 million (1979 dollars) in the ten-year period. 5. The market for additional or replacement oceanographic research ships will grow during the decade; 38 vessels for replacement or expansion and another 20 for overseas sales is a most likely estimate for a total value of over $464 million.

Concluding Statement

The conclusions reached by the committee relative to the ocean-resource opportunities and requirements affecting the maritime industry represent, on the whole, an attractive picture for that industry. However, as the study progressed, the committee became increasingly aware that many cautions should properly be observed in assessing opportunities and requirements.

Although a ten-year frame for the study was chosen as an appropriate limiting parameter, it resulted in elimination of several potentially attractive areas of future opportunity. Also, many constraints on the growth of present or new resource recovery systems were found to be important limitations on maritime industry opportunities.

It appears that the maritime industry is basically, technically ready and has the facilities needed to meet the challenge of the ocean-resources market, but the legal, regulatory, and public-policy concerns will influence importantly the pace of development. The preceding tables identify many areas where this effect is being felt.

During the study, many legal, regulatory, and public-policy changes were occurring. Many of them are encouraging from the standpoint of ocean-resource development. This progress is certainly needed and should continue with emphasis on evolving a formal, consistent, and progressive public policy to energize the many programs directed toward ocean-resource development and recovery.

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The issues associated with ocean development to determine their implication for the U.S. maritime industry have been examined. The examination embraced ocean energy systems, offshore oil and gas activities, food from the sea, deep seabed mining, and the use of ocean space. The requirements that ocean-resource development places on the maritime industry do not show sharp differences from one resource to the next. While the technological base on which the means of recovery and use of the resources can be built and deployed has been developed, more scientific work

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and technological development are needed. However, it is the committee's opinion that the true factors pacing the effort to bring many of the resources into use and to achieve the many benefits are of an economic, legal, and public-policy nature.